Catch, Escapement, and Exploitation of Chum Salmon in British Columbia, 1951-1981

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ABSTRACT

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Catch, escapement, exploitation, and stock-recruitment relationships were investigated for major stocks of British Columbia chum salmon. Annual exploitation rates on a coastwide basis were usually between 40 and 60% during 1951-1981. Catches by the gillnet and purse seine sectors of the fleet were about equal on a coastwide basis, but northern fisheries were primarily conducted by gillnetters and southern fisheries primarily by purse seines. Stock and recruitment analysis indicated that northern stocks are apparently more productive than southern ones. Exploitation rates are higher in northern fisheries than in souther ones, and exploitation rates in the northern fisheries have been generally increasing since 1951. Escapements on all stocks except for the west coast of Vancouver Island are less than the apparent optimum. The shortfall in escapement is greatest in the Johnstone Strait, Georgia Strait, Fraser River stock. Maximum sustained yield from British Columbia chum salmon stocks is estimated at 2.13 million pieces annually, but this estimate may be conservative.

Key words: British Columbia, catch, chum salmon, escapement, exploitation, stock-recruitment

RÉSUMÉ

Beacham, Terry D. 1984. Catch, escapement, and exploitation of chum salmon in British Columbia, 1951-1981. Can. Tech. Rep. Fish. Aquat. Sci. 1270: v + 201 p.

La présente étude porte sur les prises, les échappées, l'exploitation et les relations stock-recrutement dans les principaux stocks de saumon kéta de la Colombie-Britannique. Sur toute la côte, les taux annnuels d'exploitation ont habituellement varié entre 40 et 60 % de 1951 à 1981. Les prises étaient réparties presque également entre les secteurs des pêcheurs au filet maillant et à la senne coulissante, même si les activités des premiers étaient surtout concentrées au nord et celles des seconds, principalement au sud. L'analyse du stock et du recrutement porte à croire que les stocks septentrionaux sont plus productifs que leurs analogues méridionaux. Les taux d'exploitation sont plus élevés dans les pêcheries septentrionales, où ils augmentent en général depuis 1951, que dans les méridionales. Pour tous les stocks, sauf celui de la côte ouest de l'île Vancouver, les échappées sont inférieures à l'optimum apparent. Le déficit des échappées est plus élevé dans les stocks du détroit de Johnstone, du détroit de Géorgie et du fleuve Fraser. On évalue le rendement maximal soutenu annuel des stocks de saumon kéta de la Colombie-Britannique à 2,13 millions de poissons, quoiqu'il s'agisse peut-être là d'une estimation prudente.

Mots clés: Colombie-Britannique, prise, saumon kéta, échappée, exploitation, stock-recrutement

INTRODUCTION

Spawning populations of chum salmon (Oncorhynchus keta) are widespread in coastal British Columbia, and spawning occurs from July through January, with spawning occurring earlier in northern British Columbia than in the south. Life history studies have indicated that the fry migrate to the ocean after emergence from the gravel, with little or no feeding in fresh water (Neave 1953). Chum salmon mature at 3 to 5 years of age, with 4-year-olds being the most common (Pritchard 1943, Ricker 1980). Ricker (1980) reviewed in detail changes in size and age compositions of maturing chum salmon in British Columbia during 1951-1975.

There are extensive commercial fisheries in British Columbia that harvest maturing chum salmon. The major gears used in these fisheries are gillnets and purse seines. Hoar (1951) summarized the catch statistics of the British Columbia chum salmon fishery up to 1949. Since 1951, records have been kept of chum salmon catch by statistical area (Fig. 1) and gear type in British Columbia and this information has been published as annual statistical reports. The deficiencies of this system have been discussed by Healey (1982) and Wong (1983). Catches in this report were derived exclusively from this system.

Scientific management of chum salmon in British Columbia requires that the status of the major stocks be evaluated so that levels of exploitation and stock abundance that maximize catch on a continuing basis can be determined. This report examines catches, escapements, exploitation, and stock assessments of major stocks of chum salmon in British Columbia.

MATERIALS AND METHODS

Catch information by statistical area and gear was derived by methods similar to those outlined by Wong (1983). This system summarizes information from sales slips that are filled out at the time fish are delivered for processing or sold. No adjustments were made in the catch data for contribution of chum salmon of United States origin in the catch, nor for chum salmon of British Columbia origin in United States catches. No adjustments in the catch data were made for Native Indian subsistence catch.

Chum salmon spawning escapements have been recorded by Fishery Officers and Guardians and these data are the estimate used for annual escapement by statistical area. Test-fishing and mark-recovery studies may also be used to estimate escapements (e.g. Fraser River). It was assumed that escapement counts are equally reliable from 1951 to 1981 and no adjustments were made to the estimated escapements. Escapements presented in the study were derived from original spawning ground reports and have not been adjusted in any manner.

Stock-recruitment curves of the type

$$R = Se^{a\,(1-S/B)} \qquad (1)$$

where R = number of returning adults for a broodyear
S = spawning stock size that produced returns
B = replacement stock size

were fitted to the catch and escapement data. As chum salmon return mainly at 3 to 5 years of age (Pritchard 1943, Ricker 1980, Beacham and Starr 1982), age compositions in each year were necessary to assign returns in each year to a particular broodyear. When age compositions were not available, they were assigned in the following manner:

	% Age		
Stock	3	4	5
Area 1-2	15	73	12
Area 3-5	15	73	12
Area 6-10	25	67	8
Area 11-18, 28, 29	30	65	5
Area 21-27	25	70	5

Age compositions for the North and Central Coast stocks were derived from Bilton et al. 1965, 1966, 1967, 1968; Jenkinson et al. 169; and Jenkinson and Bilton 1970, 1971, 1972, 1973; L. Orman (pers. comm.); and D. Peacock (pers. comm.). Age compositions and returns for the Study Area (Statistical Areas 11-18, 28, 29) stock were provided by A. Gould (pers. comm.). Age compositions for Statistical Areas 21-27 were derived from Lightly et al. (in prep.).

Stock-recruitment curves were fit to even-numbered, odd-numbered, and all broodyears for each major stock. The parameters a, B, and mean square residual (σ^2) were derived by the linear regression of ln (R/S) on S. Optimum exploitation rates were determined by projecting cumulative catches between 1960 to 2020 and using separate stock-recruitment relationships for even- and odd-numbered broodyears. Cumulative catch was tabulated for exploitation rates of 0 to 100% in increments of 1%. For each exploitation rate and each year, the resulting recruitment from that particular escapement was the average of 100 simulations, one simulation being of the form

$$\ln (R/S) = a + \frac{a}{B} S + V \qquad (2)$$

where V is a random normal deviate of mean 0 and standard deviation σ (i.e. square root of residual mean square). Equation 2 was therefore evaluated 100 times with random values of V, subject to a normal distribution and standard deviation of σ. The average recruitment was then determined, and used subsequently in the projection. Cumulative yield versus exploitation rate were then plotted for the 60-year projections.

Once an optimum exploitation rate had been identified, projections were conducted for the period 1960-1983 at a yearly exploitation rate identified as optimum. Observed returns for 1960-1964 and previous listed age compositions were the starting points in the projection. This projection allowed the current status of the stock to be determined if a policy of a constant annual exploitation rate had been implemented in 1960.

RESULTS

CATCH AND ESCAPEMENT COASTWIDE

The catch of chum salmon in British Columbia generally declined during 1951-1965, and since 1965, catches have been higher in even-numbered years than in odd-numbered ones (Table 1, Fig. 2). Catches in 1972 and 1973 were in excess of 6 million pieces, and exploitation rates were 60% in those two years (Fig. 3). Exploitation rates have been generally in excess of 40%, but declined during times of restricted fishing (e.g. 1965, 1966, 1981). Closures in the South Coast in 1965 and 1966 allowed escapements to increase, but escapements during 1974-1981 were below the level of over 4 million achieved in 1968.

The dominant gears in the fishery are purse seines and gillnets (Fig. 4), and on a coastwide basis, the catch of the two gears is similar (Figs. 4,5). Before 1970, trollers caught few chum salmon (Table 1, Fig. 4), but their proportion of the catch, while still less than 5% annually, has been increasing since 1970. Catch-per-unit efforts for trollers have also been increasing since 1970 (Table 2). Catches for each gear in each Statistical Area are illustrated in Appendix A.

The coastwide catch of chum salmon was subdivided into smaller areas in order to evaluate differences in trends among areas. Catches in the North and Central Coast (Statistical Areas 1-10) have ranged from 0.5 to 2.7 million pieces (Fig. 6), with the highest catches recorded in 1972 and 1973. Catches of South Coast and Fraser River chum salmon (Statistical Areas 11-20, 28, 29) declined from 1951 to the closures in 1965 and 1966, and except for 1972 and 1973, have not recovered to the level observed before 1955. West coast of Vancouver Island chum salmon (Statistical Areas 21-27) have shown variable catches, with over 1.3 million pieces recorded in 1972.

Catches of chum salmon in the North and Central Coast regions have generally been greater than in the South Coast region since 1961 (Fig. 7), and in odd-numbered years have been in excess of 60% of the coastwide catch. West coast of Vancouver Island chum salmon comprised 20% of the coastwide catch during 1956-1961 and again in 1972. Catches and escapements were examined for all Statistical Areas on an annual basis. Catches are illustrated in Appendix B and escapements in Appendix C. Catch and exploitation history on a regional basis are reviewed next.

North and Central Coast

Escapement of chum salmon in the North and Central Coast regions was nearly 2 million fish in 1951 and 1952, but has been generally less than 1 million fish since 1974 (Fig. 8). The annual exploitation rate since 1955 has usually been at least 50%, and exceeded 60% in some years (Fig. 9).

The dominant gear in the fishery in the North and Central Coast region is gillnet (Fig. 10), and on an annual basis accounts for about 65% of the catch (Fig. 11). Purse seiners account for the remainder of the catch, with trollers accounting for less than 2% of the catch, but this proportion is increasing.

South Coast

Escapement of chum in the South Coast declined from 2.3 million chum salmon in 1951 to about 0.7 million in 1965 (Fig. 12). Escapements have increased since 1965, to about 2.1 million in 1980 and 1981. After 1973, exploitation rates were in excess of 40% in even-numbered years, and after 1975, exploitation rates were less than 20% in odd-numbered years (Fig. 13). Exploitation rates have tended to increase since 1968 in North and Central Coast fisheries (Fig. 9), whereas those in the South Coast have tended to decline (Fig. 13).

Catches declined in the South Coast during 1951 to 1965 (Fig. 14), but the decline was proportionately greater in purse seiners than in gillnetters (Fig. 15). Since 1972, purse seiners have been the dominant gear in the fishery, accounting for at least 60% of the reported landings. Trollers have accounted for an increasing proportion of the catch, reaching 15% of the catch in 1979 (Fig. 15).

The previous results have indicated that chum salmon in the North and South Coasts have been harvested at different rates and have had some different trends in catch and escapement. The major chum salmon stocks of British Columbia will now be considered in detail in terms of catch, escapement, and stock assessment.

ASSESSMENT OF MAJOR CHUM SALMON STOCKS

Queen Charlotte Islands (Statistical Areas 1-2)

Catch and escapement

Escapement of chum salmon in the Queen Charlotte Islands declined rapidly during 1951-1955 from in excess of 1 million fish in 1952 to 70 thousand in 1955 (Fig. 16). During 1955 to 1964, escapement increased to 750 thousand fish, but declined subsequently to 200 thousand fish in 1981. Catch has been variable, and has exceeded 250 thousand pieces in only 1964, 1972, and 1973 (Fig. 16).

Escapement of chum salmon on the Queen Charlotte Islands has declined since 1964. During 1965 to 1981, exploitation rates were in excess of 50% in only 1972 and 1973, and have usually been between 20 and 40% (Fig. 17). These exploitation rates are based upon the assumption that all chum salmon caught in Statistical Areas 1 and 2 are of Queen Charlotte Islands origin. As indicated later, this is unlikely to be the case, so that escapements have declined at probable rates of exploitation of Queen Charlotte Islands chum salmon at less than 30 to 40%.

Catches have been split about equally between gillnetters and seiners, although trollers have taken an increasing portion of the catch since 1974 (Figs. 18 and 19). Trollers accounted for in excess of 20% of the catch in 1979, due largely to decreased catches of the seine and gillnet sectors of the fleet.

Stock and recruitment

Stock and recruitment curves were compared for even-numbered broodyears, odd-numbered broodyears, and all broodyears on the assumption that all chum salmon caught in Statistical Areas 1 and 2 were of Queen Charlotte Islands origin. When age composition of the catch was unknown in a particular year, a distribution of 15% age 3 years, 73% age 4, and 12% age 5 was assumed. The resulting escapement, broodyear returns, and rates of return are indicated in Table 2. Stock and recruitment curves based upon the data in Table 2 are illustrated for all broodyears (Fig. 20), odd-numbered broodyears (Fig. 21), and even-numbered broodyears (Fig. 22). Odd numbered broodyears were more productive than even-numbered broodyears (Table 4). Based upon the assumption that there are no interceptions of other chum salmon in Statistical Areas 1 and 2 other than the Queen Charlotte Islands stock, optimum rate of exploitation was estimated to be about 55% with an optimum escapement of 210,000 chum salmon.

Exploitation rates of Queen Charlotte Islands chum salmon have been generally less than 50% since 1956 (Fig. 17), yet escapement has declined since 1964 (Fig. 16). The exploitation rate since 1964 has been about 35%, and escapement has declined during the same period. The optimum exploitation rate for this stock must be less than 35%, and probably is in the 25-30% range. The optimum exploitation rate derived from stock-recruitment analyses is clearly too high, so that the Queen Charlotte Island chum salmon stock is actually less productive than the stock and recruitment analysis indicates. It may be that fisheries in the region intercept chum salmon destined for other areas, so that assigning all the catch in Statistical Areas 1 and 2 to the Queen Charlotte Islands stock would make the stock appear more productive than it actually is.

North Coast (Statistical Areas 3-5)

Catch and escapement

Escapement of chum salmon in the North Coast stock has been relatively stable since 1955, generally ranging between 50 and 150 thousand fish (Fig. 23). Escapements during 1972-1974 were in excess of 100 thousand fish, but the 1981 escapement was the lowest of any year during 1951-1981. Catches in the region have tended to increase since 1963, and catches tend to be greater in even-numbered years than in odd-numbered ones (Fig. 23). Catches have generally ranged between 100 and 400 thousand pieces annually.

Apparent exploitation rates in this stock have rarely been less than 60%, and exploitation rates have generally increased since 1951 (Fig. 24). Exploitation rates in excess of 80% have been recorded in 1968, 1970, and 1980. Exploitation rates as well as catches for this stock have been increasing since 1960, but there has been no marked decline in escapements.

Gillnetters have been the dominant gear in the region, generally accounting for about 70-80% of the catch (Figs. 25 and 26). Seiners account for the remainder of the catch, with trollers comprising about 1-2% of the catch.

Stock and recruitment

All chum salmon caught in Statistical Areas 3-5 were assumed to be derived from the North Coast stock. If the age composition of the returning adults was unknown in a particular year, a distribution of 15% age 3, 73% age 4, and 12% age 5 was assumed. The escapements and resultant returns for the 1948-1977 broodyears are indicated in Table 5. Stock and recruitment curves for the data in Table 5 are illustrated in Figs. 27-29. Even-numbered broodyears are more productive than odd-numbered ones (Table 6). Under the assumption that there are no interceptions in the areas, the optimum exploitation rate was 77%, with an optimum escapement of 68,000 fish.

The yield curve based upon projected cumulative catch between 1960 and 2020 is illustrated in Fig. 30. Yield declines sharply at exploitation rates in excess of 80%. Optimum exploitation rates, optimum escapements, and the yield curve will indicate values in excess of optimum for the stock if interceptions of chum salmon from other areas in Statistical Areas 3-5 is greater than interceptions of North Coast (areas 3-5) chum salmon in areas other than Statistical Areas 3-5. An optimum exploitation rate in excess of 75% seems unusually high for chum salmon, so that it seems likely that there could be interceptions of other chum salmon stocks in North Coast fisheries.

Central Coast (Statistical Areas 6-10)

Catch and escapement

Catch and escapement of Central Coast chum salmon declined during 1951-1959, increased through to 1973, declined to 1976, and increased to 1981 (Fig. 31). Catches were in excess of 1 million pieces in 1953, 1957, 1968, 1970, 1972, and 1973, and thus the Central Coast area is a major chum salmon fishery in British Columbia. The Central Coast region may be conveniently divided into 2 areas, namely Statistical Areas 6-8 and 9-10 (Rivers and Smith Inlets). Catches and escapements are greater in Areas 6-8 (Fig. 32) than in Areas 9-10 (Fig. 33). The dominant fishery in the Central Coast occurs in Areas 6-8, with about 650 thousand pieces landed annually between 1951-1981. Only 50 thousand pieces were landed annually in Areas 9-10 between 1951-1981. There has been no general trend in chum salmon escapements in either of the two subareas of the Central Coast.

Exploitation rates in the Central Coast fishery have been generally increasing since 1951 (Fig. 34). Exploitation rates in the 1970s were generally between 50 to 70%, and in 1980 an exploitation rate of about 75% was observed. Apparent exploitation rates before 1970 have been lower in Areas 6-8 (Fig. 35) than in Areas 9-10 (Fig. 36). Exploitation rates in the Rivers

Inlet chum salmon fishery declined during 1977-1981, and that in Smith Inlet declined after 1971. Conservation measures instituted for sockeye salmon have reduced the incidental catch of chum salmon in both fisheries.

The Central Coast fishery is conducted mainly by gillnetters and purse seiners, with gillnetters the dominant gear for chum salmon (Figs. 37,38). Gillnetters generally account for in excess of 60% of the catch. Purse seiners account for a larger proportion of the catch in areas 6-8 (Figs. 39,40) than in Areas 9-10 (Figs. 41,42). Gillnetters have generally accounted for in excess of 80% of the catch in areas 9-10 since 1960. Areas 9 and 10 have been closed to seiners since 1979, and gillnetters have accounted for virtually 100% of the catch since then.

Stock and recruitment

If age compositions of the returning adults were unknown in a particular year, a distribution of 25% age 3, 67% age 4, and 8% age 5 was assumed. The escapements and returns for the 1948-1977 broodyears are listed in Table 7. Stock and recruitment curves for the data listed in Table 7 are illustrated in Figs. 43-43. Replacement levels of spawning stock are 1.0 million and 1.8 million fish for odd- and even-numbered broodyears, respectively. Odd numbered broodyears are more productive than even numbered broodyears and thus can maintain a higher optimum exploitation rate (Table 8). The optimum exploitation rate for all broodyears is 54% at an optimum escapement of 576 thousand fish.

The yield curve based upon projected cumulative catches during 1960-2020 indicates that there is a rapid decline in yield at sustained exploitation rates above 65% annually (Fig. 46). There is a marginal increase in yield in increasing exploitation rate from 50 to 60% (Figs. 46,47). During 1970-1981, the exploitation rate has exceeded 60% annually in 5 instances, and this will lead to declining escapements if exploitation is not reduced.

Johnstone Strait, Georgia Strait, Fraser River (Statistical Areas 11-18, 28, 29)

Catch and escapement

Chum salmon returning to spawn in their natal streams in Johnstone Strait, Georgia Strait, and the Fraser River migrate primarily through Johnstone Strait. Because it is difficult to allocate the catch to respective stocks, chum salmon from this region have been grouped into a unit stock for management purposes. Chum salmon from this region are commonly known as the Study Area stock. Tagging studies on the stock have been summarized by Anderson and Beacham (1983).

Catches of chum salmon in the Study Area declined during 1951 to 1966 (Fig. 48). Rapidly declining stock size in the early 1960s prompted complete closures of the chum salmon fishery in 1965 and 1966. The stock then rapidly recovered, so that by 1973 a catch of nearly 3 million pieces and an escapement of 2 million fish were recorded. Catches have declined since 1973, and have been higher in even-numbered years than in odd-numbered ones (Fig. 48). Escapements have rarely exceeded 1.5 million fish since 1973, and have been less than 1 million in 1975 and 1979.

The exploitation rate of the Study Area stock generally exceeded 50% in the 1950s, but then declined in the 1960s as stock size declined significantly (Fig. 49). After 1975, exploitation rates have been less than 20% in the odd-numbered years, but in excess of 40% in the even-numbered years. Catches and exploitation rates have not returned to the levels experienced in the 1950s, and there as been a general trend for a decline in exploitation rates since 1970 (Fig. 49).

The fishery in Johnstone Strait is primarily a purse seine fishery, with purse seiners accounting for about 75% of the catch since 1970 (Figs. 50,51). The gillnet portion of the catch has declined from about 40% in 1964 to 25% in 1981. Prior to 1975, the chum salmon fishery in Georgia Strait was conducted primarily by gillnetters, with this gear accounting for in excess of 70% of the catch (Figs. 52,53). By 1975, purse seiners accounted for, on average, 50% of the catch. Trollers accounted for 50% of the catch in 1977. Catches of chum salmon in Burrard Inlet and the Fraser River declined rapidly in the 1950s, and have not recovered (Fig. 54). The fishery is conducted entirely by gillnetters.

Stock and recruitment

Escapements and subsequent returns for the 1956 to 1977 broodyears were provided by A. P. Gould (pers. comm.) and are listed in Table 9. Stock and recruitment curves were derived from those data and are illustrated in Figs. 55-57. Even-numbered broodyears were more productive than odd-numbered ones, and this accounts for catches being higher in even-numbered years than in odd-numbered ones. The optimum exploitation rate for the even-numbered broodyear was estimated 27% (Table 10), a rate that has always been exceeded since the fishery was reopened after the 1965 and 1966 closures. If catches are to increase from this stock, exploitation rates in even-numbered years must decline.

The yield curve based upon a 60-year projection during 1960-2020 indicates that yield falls off rapidly when the stock is exploited on a sustained basis in excess of 35% annually (Fig. 58). Long-term yield at a sustained 50% annual exploitation rate is only about one-half of the yield at 30% (Fig. 59). In order to increase yield from this stock, annual exploitation rates should not exceed 30%, no matter how large the returning stock is.

The effects on catch and stock size were investigated if a policy of an annual 30% exploitation rate were adopted in 1960. Observed returns from 1960-64 were used in the projection, as was a 30% age 3, 65% age 4, and 5% age 5 age composition. The resulting recruitment from each escapement was the average of 100 simulations of equation 2. If a policy of 30% annual exploitation rate had been followed since 1960, projected catches for 1983 and 1984 were approximately 944,000 and 1,029,000 pieces, respectively (Table 11). Cumulative projected catches under a policy of 30% annual exploitation were compared with observed catches for the period 1960-1981. Observed catches and projected catches were identical by 1981 (Fig. 60). During this period there would have been no net loss of catch to industry, and by 1981 escapements were projected to be in excess of 2 million fish (Table 11), instead of the 1.5 million actually observed (Fig. 48).

Rehabilitation of the Study Area chum salmon stock clearly involves reducing the exploitation rate in even-numbered years to 30%, regardless of the size of the returning stock. The projection indicates that an annual exploitation rate of 30% in both odd and even years will allow both catches and escapements to increase from this stock in a short period.

Juan de Fuca Strait (Statistical Areas 19-20)

Catch

Catches of chum salmon in Areas 19 and 20 have been minor, although in 1972 and 1973 they were in excess of 100 thousand pieces (Fig. 61). The fishery was conducted primarily by gillnetters during 1956 to 1971, but purse seiners have accounted for a significant portion of the catch since 1972 (Fig. 62). Chum salmon caught in this area are largely of southern Georgia Strait and Fraser River origin.

West Coast Vancouver Island (Statistical Areas 21-27)

Catch and escapement

Catches of chum salmon in Statistical Areas 21-27 have been variable, ranging from less than 7000 pieces annually during 1965 to 1969, to about 1.5 million pieces in 1972 (Fig. 63). Catches were in excess of 800 thousand pieces in 1980. Escapements generally declined during 1951 to 1963, but increased during the period of restricted catches during 1965 to 1969 (Fig. 63). Escapements have generally been in excess of 300 thousand pieces annually since 1975.

As catches have been variable in this stock, exploitation rates have also been quite variable. Exploitation rates were in excess of 60% in 1956, 1972, and 1980, but less than 30% during 1963 to 1971 (Fig. 64).

The fishery off southwestern Vancouver Island was a gillnet and seine fishery up to 1963, but closures of the gillnet and seine fishery during 1963 to 1969 allowed trollers to account for 100% of the catch (Figs. 65,66). However, the number of pieces caught are quite small (Fig. 65). Trollers again accounted for in excess of 50% of the catch in 1975, 1977, and 1979, when catches of the gillnet and seine fleet were reduced. The troll catch in the northwestern Vancouver Island fishery has been generally increasing since 1969 (Fig. 62), but still accounts for a small proportion of the catch in years when the gillnet and seine fleet participate in the fishery (Fig. 68).

Stock and recruitment

Returns for the 1956 to 1959 broodyears were derived from Roberts (1970), those for the 1967 to 1977 broodyears from Lightly et al. (in prep.), and the remainder were derived by assuming an age composition of 25% age 3, 70% age 4, and 5% age 5, as outlined by Lightly et al. Stock and recruitment curves derived from the data in Table 12 are outlined in Figs. 69-71. Odd-numbered broodyears were more productive than even-numbered ones (Figs. 70,71, Table 13). The optimum exploitation rate for the odd-numbered broodyears was nearly twice that for the even-numbered ones. The optimum rate of exploitation for the stock was estimated at 40% (Table 13).

The yield curve based upon catches projected between 1960 and 2020 indicates that yield declines rapidly at a sustained annual exploitation rate of in excess of 55% (Fig. 72). Exploitation in any year should not exceed 45 to 50% in order to allow for stock rebuilding.

The effects on catch and stock size were investigated if a policy of an annual 45% exploitation rate were adopted in 1960. Observed returns for 1960-1964 were used in the projection, as well as a 25% age 3, 70% age 4, and 5% age 5 age composition. If a policy of 45% annual exploitation had been followed since 1960, the projected catches for 1983 and 1984 were 249 and 212 thousand pieces, respectively (Table 14).

DISCUSSION

Analysis of the stock and recruitment information suggests that chum salmon stocks of the Queen Charlotte Islands, North Coast, and Central Coast are more productive than those of the Study Area (Johnstone Strait, Georgia Strait, and Fraser River) and the West Coast of Vancouver Island. The northern stocks may actually be more productive than the southern ones, or there may be interceptions in the northern fisheries of chum salmon bound for Alaskan or southern British Columbia rivers. As outlined by Wong (1982), it is currently believed that there are no interceptions of southern British Columbia chum salmon in the northern fisheries. There are several pieces of information to suggest that this may not be a valid assumption. Exploitation rates in the North Coast fishery (Statistical Area 3-5) have been increasing since 1951 (Fig. 24). They have also been increasing in the Central Coast fishery (Fig. 35). While exploitation rates have been increasing in these fisheries, they have been declining in the Study Area fishery (Fig. 49). These trends may be coincidental, but could be indicative of southern British Columbia chum salmon in the northern fisheries.

Tagging studies have been conducted on the Central Coast chum salmon stock. A maximum of about 3% of the tags returned from any tagging site in the Central Coast was reported from southern Statistical Areas (Anon. 1982). However, there may have been differences in the recovering and reporting tags in the Central Coast and South Coast regions, so that a value of 3% may underestimate the contribution of southern British Columbia chum salmon to the northern fisheries. Chum salmon tagged in the Central Coast and recovered in the Johnstone Strait fisheries had been tagged in July and August (Anon. 1982), so that a portion of the Central Coast catches in July and August may be derived from the Study Area stock.

Chum salmon returning to spawn in the North and Central Coast fisheries have usually entered the rivers by mid-September (Farwell, M. pers. comm.). There should presumably be few catches of chum salmon in northern British Columbia in September and October. Catches by week for late August to mid-October are illustrated for the 1980 chum salmon fishery for British Columbia in Appendix D. There were substantial catches of chum salmon in the

Queen Charlotte Islands fishery in late September and October, and substantial catches in the Central Coast fishery in September. As these catches may be late if the chum salmon were bound for rivers in northern and central British Columbia, it may be possible that there were some chum salmon of southern origin in these catches.

On a coastwide basis, catch and escapement of British Columbia chum salmon have shown no unidirectional trend during 1951-1981. It is clear that some stocks are over-exploited. Escapements of Queen Charlotte chum salmon have been declining since 1965, although the stock has been generally exploited at less than the rate identified as optimum by a stock and recruitment analysis. Wong (1982) has suggested that a rate of 25% is the optimum for this stock. The North Coast stock is exploited at the rate identified as optimum, but if there are interceptions in the fishery, the optimum rate is lower than the 75-80% rate derived from stock and recruitment analysis. The optimum rate of exploitation in the Central Coast stock was identified as 55%, and this rate has been often exceeded (Figs. 34,35). Exploitation rates of the Study Area stock are clearly in excess of the optimum rates in even-numbered years (Fig. 49), and projections based upon an annual exploitation rate of 30% indicate that long term yield from this stock could be increased if the 30% harvest rate policy were implemented. Wong (1982) indicated that the optimum rate of exploitation is about 55% for this stock. However, this is likely an overestimate. Exploitation rates for the West Coast Vancouver Island chum salmon stock have generally been less than the optimum rate, but escapements have not increased markedly.

The coastwide share of the chum salmon catch between gillnetters and purse seiners has been relatively constant at about 50% for each gear. The troll portion of the catch generally increased when the net fisheries were restricted.

Productivity of chum salmon broodyear is different in even- and odd-numbered years. Productivity is generally higher in broodyears when pink salmon are absent than when they are present. For example, in the Johnstone Strait, Georgia Strait, and Fraser River chum salmon stock, even-numbered broodyears were more productive than odd-numbered ones. In even-numbered years, pink salmon are absent from the Fraser River, and chum salmon have higher survival, as indicated by Beacham and Starr (1982). In the West Coast Vancouver Island stock, odd-numbered broodyears were more productive. In this area, pink salmon are absent in odd-numbered years, but are present in even-numbered years in the northwestern area of Vancouver Island. Chum salmon in odd-numbered broodyears on the Queen Charlotte Islands have higher productivity than those in even-numbered ones. Pink salmon are also markedly less abundant on the Queen Charlotte Islands in odd years than in even ones. It seems that there are interspecific interactions between pink and chum salmon, and that chum salmon survive better in years when pink salmon are absent as compared with when they are present. Investigations into competitive interactions between these 2 species could be conducted.

If all chum salmon fisheries in British Columbia were conducted with stocks at optimum escapements, the maximum sustained catch is projected to be 1.51 million pieces in odd-numbered years and 2.44 million pieces in even-numbered years. With all broodyears combined, the maximum sustained yield is estimated at 2.13 pieces annually. However, the largest stock

(Johnstone Strait-Fraser River) may be more productive than the analysis suggests, so that maximum sustained yields are probably in excess of 2.13 million pieces. Average annual catch in British Columbia is near this level at present (Fig. 2). As enhancement facilities produce higher numbers of returning adults, maximum sustained yield should increase, provided that wild stocks are not overexploited in our eagerness to harvest these enhanced fish.

ACKNOWLEDGMENTS

Mr. Fred Wong made accessible the data bases which upon the catch and escapement analysis was based. Mr. Bruce Bernard designed the computer software for the graphics in this report, as well as many of the computer programs used in the stock and recruitment analyses and projections. Mr. Bernard's assistance in this project was invaluable, and the study could not have been conducted in its present form without his programming and computer graphics ability. Valuable suggestions for improvement of the manuscript were made during review by Field Services biologists (A. Gould, L. Orman, D. Peacock).

REFERENCES

Anderson, A. D. and T. D. Beacham. 1983. The migration and exploration of chum salmon stocks of the Johnstone Strait-Fraser River Study Area, 1962-1970. Can. Tech. Rep. Fish. Aquat. Sci. No. 1166: 125 p.

Anonymous. 1982. Central Coast salmon tagging report for 1976, 1978, and 1979. Contract report by Aquatic Resources Limited. 397 p.

Beacham, T. D. and P. Starr. 1982. Population biology of chum salmon, Oncorhynchus keta, from the Fraser River, British Columbia Fish. Bull. 80: 813-825.

Bilton, H. T., E. A. R. Ball, and D. W. Jenkinson. 1967. Age, size and sex composition of British Columbia chum salmon catches from 1957 to 1963. Fish. Res. Board Can., Circular (Stat. Ser.) 26, 4 p., 192 tables.

Bilton, H. T., D. W. Jenkinson, E. W. Stolzenberg, and M. M. Aarts. 1966. Age composition of 1965 British Columbia sockeye, chum and pink salmon catches. Fish Res. Board. Can., Circular (Stat. Ser.) 27, 4 p., tables.

1967. Age composition of 1966 British Columbia sockeye, chum and pink salmon catches. Fish. Res. Board Can. MS Rep. 943, 8 p., tables.

Bilton, H. T., D. W. Jenkinson, E. W. Stolzenberg, and M. M. Aarts. 1968. Age composition of 1967 British Columbia sockeye, chum and pink salmon catches. Ibid. 1001, 9 p., tables.

Bilton, H. T., D. W. Jenkinson, E. W. Stolzenberg, S. A. M. Ludwig, and M. M. Aarts. 1965. Age composition of 1964 British Columbia sockeye, chum and pink salmon catches. Fish. Res. Board Can., circular (Stat. Ser.) 16, 7 p., tables.

Healey, M. C. 1982. Catch, escapement and stock-recruitment for British Columbia chinook salmon since 1951. Can. Tech. Rep. Fish. Aquat. Sci. 1107: 77 p.

Hoar, W. S. 1951. The chum and pink salmon fisheries of British Columbia, 1917-1947. Bull. Fish. Res. Board Can. 90: 1-46.

Jenkinson, D. W., M. M. Aarts, and H. T. Bilton. 1969. Age composition of 1968 British Columbia sockeye and chum catches. Fish. Res. Board Can. MS Rep. 1052, 9 p., numerous tables.

1971. Age composition of 1970 British Columbia sockeye, chum and pink salmon catches. Ibid. 1142, 8 p., numerous tables.

1972. Age composition of 1971 British Columbia sockeye, chum and pink salmon catches. Ibid. 1196, 9 p., numerous tables.

1973. Age composition of 1972 British Columbia sockeye, chum and pink salmon catches. Ibid. 1253, 4 p., numerous tables.

Neave, F. 1953. Principles affecting the size of pink and chum salmon populations in British Columbia. J. Fish. Res. Board Can. 9: 450-491.

Pritchard, A. L. 1943. The age of chum salmon taken in commercial catches in British Columbia. Fish. Res. Board Can., Progress Rept. (Pac.) 54: 9-11.

Ricker, W. E. 1980. Changes in the age and size of chum salmon (Oncorhynchus keta). Can. Tech. Rep. Fish. Aquat. Sci. 930: 99 p.

Wong, F. Y. C. 1982. Analysis of stock-recruitment dynamics of British Columbia salmon. M. Sc. thesis, University of British Columbia. Vancouver, B.C. 221 p.

1983. Historical salmon commercial catch data system of the Fisheries Research Branch, Department of Fisheries and Oceans, Pacific Region. Can. Tech. Rep. Fish. Aquat. Sci. No. 1156: 94 p.

Table 1. Commercial catch (pieces) of chum salmon in British Columbia, 1951-1981.

Year	Gillnet	Seine	Troll	Total
1951	1595780	1706770	9320	3311820
1952	952780	949110	1050	1902940
1953	1668771	1843130	934	3512835
1954	1666650	2270000	920	3937570
1955	1702670	536160	610	1239440
1956	1155940	1300230	2100	2458270
1957	1505170	904470	2450	2412090
1958	1674720	1514480	2550	3191750
1959	1069760	943190	2380	2015330
1960	97620	859050	1410	1836750
1961	724370	489360	3770	1217500
1962	872540	619230	4220	1495990
1963	929670	525650	7900	1463220
1964	1070540	1171110	11140	2252790
1965	366630	258600	7900	633130
1966	734430	572150	4130	1310710
1967	692010	409380	3660	1105050
1968	1856970	1230390	7290	3094650
1969	855710	449570	5160	1310440
1970	2364310	1280290	34770	3679370
1971	843780	405400	13790	1262970
1972	2989540	3075570	10850	6075960
1973	3024830	3176890	23310	6225030
1974	1387910	797090	16780	2201780
1975	597540	534190	15430	1147160
1976	831080	1054270	15690	1901040
1977	579300	486970	21890	1088160
1978	1240340	1677390	60950	2978680
1979	398700	427320	40290	866310
1980	1814550	1913880	67600	3796030
1981	587850	507310	27780	1122940

Table 2. Effort (day fished) and catch per day of chum salmon for commercial vessels in British Columbia, 1963-1981. The days fished value is an annual total and includes effort not directed towards chum salmon.

	Gillnet		Seine		Troll	
Year	Effort	C.P.U.E.	Effort	C.P.U.E.	Effort	C.P.U.E.
1963	109991	7.8	11673	43.7	122636	0.1
1964	124524	7.7	10756	100.4	137625	0.1
1965	95137	3.1	750	24.5	132232	0.0
1966	106055	5.6	10922	45.4	138253	0.0
1967	121821	3.7	12240	20.9	137683	0.0
1968	133398	11.5	14440	73.0	14475	0.0
1969	97539	8.4	8899	49.4	130321	0.0
1970	126441	16.7	15029	75.0	137981	0.2
1971	103644	6.5	10840	28.1	149169	0.1
1972	107921	27.4	14660	208.9	136619	0.1
1973	108114	27.9	16789	189.1	128862	0.2
1974	88230	15.7	13094	60.9	122851	0.1
1975	60363	9.9	10570	50.5	118387	0.1
1976	77651	10.7	14021	75.2	130392	0.1
1977	83802	6.9	16528	29.5	151588	0.1
1978	68930	18.0	13287	126.2	148924	0.4
1979	50551	7.6	12141	35.2	162327	0.2
1980	50739	30.3	12161	148.8	193301	0.3
1981	52173	11.1	10286	49.3	164079	0.2

Table 3. Escapement and resulting returns for 1953-1977 broodyears for Queen Charlotte Islands chum salmon. When age compositions of the catch were not available in a year, a distribution of 15% age 3, 73% age 4, and 12% age 5 was assumed. Estimates are listed to the nearest thousand.

Broodyear	Escapement	Returns	R/S
1953	345	455	1.32
1954	573	314	0.55
1955	70	136	1.94
1956	13	227	1.71
1957	429	357	0.83
1958	277	471	1.70
1959	68	446	6.56
1960	228	1299	5.70
1961	290	1011	3.49
1962	376	680	1.81
1963	365	548	1.50
1964	746	608	0.82
1965	444	459	1.03
1966	600	532	0.89
1967	47	485	1.19
1968	451	831	1.84
1969	300	798	2.66
1970	355	505	1.42
1971	344	355	1.03
1972	338	310	0.92
1973	326	434	1.33
1974	217	410	1.89
1975	290	404	1.39
1976	224	397	1.77
1977	268	276	1.03

Table 4. Parameters for stock and recruitment curves for Queen Charlotte Islands chum salmon. Returns and spawners are listed in Table 3. Yield and spawners are listed to the nearest thousand.

Parameter	Combined	Broodyear	
		Odd years	Even years
a	1.28	1.54	1.20
B	510	439	552
maximum sustained yield	245	269	230
optimum escapement	209	172	230
optimum exploitation rate	54%	61%	50%

Table 5. Escapement and resulting returns for 1948-1977 for North Coast (areas 3-5) chum salmon. When age compositions of the catch were not available in a year, a distribution of 15% age 3, 73% age 4, and 12% age 5 was assumed. Estimates are listed to the nearest thousand.

Broodyear	Escapement	Returns	R/S
1948	71	298	4.20
1949	85	306	3.60
1950	91	317	3.48
1951	138	211	1.53
1952	121	426	3.52
1953	79	479	6.06
1954	139	402	2.89
1955	36	253	7.03
1956	67	283	4.22
1957	117	397	3.39
1958	105	122	1.16
1959	117	184	1.57
1960	46	392	8.52
1961	127	172	1.35
1962	56	370	6.61
1963	75	141	1.88
1964	116	529	4.56
1965	58	86	1.48
1966	79	373	4.72
1967	68	127	1.87
1968	80	726	9.08
1969	42	396	9.43
1970	55	418	7.60
1971	44	170	3.86
1972	135	182	1.35
1973	102	419	4.10
1974	166	352	2.12
1975	52	323	6.21
1976	91	423	4.65
1977	99	173	1.75

Table 6. Parameters for stock and recruitment curves for North Coast (Statistical Area 3-5) chum salmon. Returns and spawners are listed in Table 5. Yield and spawners are listed to the nearest thousand.

Parameter	Combined	Broodyear	
		Odd years	Even years
a	2.23	2.10	2.56
B	198	173	204
maximum sustained yield	228	143	301
optimum escapement	68	61	66
optimum exploitation rate	77%	74%	82%

Table 7. Escapement and returns for 1948-1977 Central Coast (Areas 6-10) chum salmon. When age compositions of returns were not available in a year, a distribution of 25% age 3, 67% age 4, and 8% age 5 was assumed. Estimates are listed to the nearest thousand.

Broodyear	Escapement	Returns	R/S
1948	376	1314	3.49
1949	911	1795	1.97
1950	852	1673	1.96
1951	929	1025	1.10
1952	645	1027	1.59
1953	916	1437	1.57
1954	697	1878	2.69
1955	384	289	1.01
1956	459	549	1.20
1957	529	1017	1.92
1958	681	1359	2.00
1959	256	1004	3.92
1960	415	2391	5.76
1961	277	567	2.05
1962	702	1647	2.35
1963	643	784	1.22
1964	743	2442	3.29
1965	225	420	1.87
1966	994	2652	2.26
1967	645	1076	1.67
1968	1070	2664	2.49
1969	390	2540	6.51
1970	791	1337	1.69
1971	576	739	1.28
1972	776	760	0.98
1973	988	745	0.75
1974	704	1160	1.65
1975	340	1072	3.15
1976	386	1246	4.36
1977	377	1152	3.06

Table 8. Parameters for stock and recruitment curves for Central Coast (Statistical Areas 6-10) chum salmon. Returns and spawners are listed in Table 7. Yield and spawners are listed to the nearest thousand.

Parameter	Combined	Broodyear	
		Odd years	Even years
a	1.30	1.39	1.29
B	1408	1048	1830
maximum sustained yield	676	537	845
optimum escapement	576	422	749
optimum exploitation rate	54%	56%	53%

Table 9. Escapement and resulting returns for 1956-1977 broodyears for Johnstone Strait, Georgia Strait, Fraser River (Statistical Areas 11-18, 28, 29) chum salmon. Estimates are listed to the nearest thousand.

Broodyear	Escapement	Returns	R/S
1956	489	1229	2.51
1957	1002	1437	1.43
1958	1149	301	0.26
1959	883	1465	1.66
1960	720	1148	1.59
1961	647	506	0.78
1962	715	993	1.39
1963	698	553	0.79
1964	884	2890	3.27
1965	401	1336	3.33
1966	983	2831	2.88
1967	709	657	0.93
1968	1877	4686	2.50
1969	1070	4578	4.28
1970	1157	1112	0.96
1971	721	886	1.23
1972	1971	2704	1.37
1973	1820	1551	0.85
1974	1434	3148	2.20
1975	754	898	1.19
1976	1287	2104	1.63
1977	1385	1973	1.42

Table 10. Parameters for stock and recruitment curves for Johnstone Strait, Georgia Strait, and Fraser River (Study Area) chum salmon. Returns and spawners are listed in Table 9. Yield and spawners are listed to the nearest thousand.

		Broodyear	
Parameter	Combined	Odd years	Even years
a	0.48	0.50	0.58
B	6190	2543	5586
maximum sustained yield	814	360	949
optimum escapement	2887	1206	2566
optimum exploitation rate	22%	23%	27%

Table 11. Projected returns, catches, and escapements by managing Study Area chum salmon stock for an annual 30% exploitation rate since 1960. Observed returns for 1960-1964 and an age composition of 30% age 3, 65% age 4, and 5% age 5 were used. Estimates are listed to the nearest thousand.

Broodyear	Returns	Catch	Escapement
1960	1400	420	980
1961	1008	302	705
1962	976	292	683
1963	1349	404	944
1964	1722	516	1205
1965	1307	392	915
1966	1523	457	1066
1967	1791	537	1254
1968	1897	569	1328
1969	1755	526	1229
1970	2047	614	1433
1971	2103	361	1472
1972	2316	695	1621
1973	2136	640	1495
1974	2544	763	1781
1975	2519	755	1763
1976	2806	841	1964
1977	2528	758	1769
1978	2962	888	2073
1979	2938	881	2056
1980	3311	993	2318
1981	2950	885	2065
1982	3720	1116	2604
1983	3149	944	2204
1984	3431	1029	2401
1985	3104	931	2173
1986	3836	1150	2685

Table 12. Escapement and resulting returns for 1953-1977 broodyears for West Coast Vancouver Island chum salmon. Returns for 1956-1959 broodyears were derived from Roberts (1970) and those for 1967-1977 broodyears from Lightly et al. (in prep.). An age composition of 25% age 3, 70% age 4, and 5% age 5 was assumed for the remainder. Estimates are listed to the nearest thousand.

Broodyear	Escapement	Returns	R/S
1953	837	652	1.28
1954	960	698	1.38
1955	734	146	5.00
1956	698	336	2.08
1957	843	367	2.29
1958	310	503	0.62
1959	303	292	1.04
1960	352	561	0.63
1961	283	218	1.30
1962	305	236	1.29
1963	325	174	1.86
1964	495	350	1.41
1965	420	230	1.82
1966	450	330	1.36
1967	318	305	1.04
1968	2279	570	3.99
1969	800	357	2.24
1970	354	347	1.02
1971	356	318	1.12
1972	447	879	0.51
1973	226	703	0.32
1974	763	541	1.41
1975	150	279	0.54
1976	314	338	0.93
1977	1391	331	4.19

Table 13. Parameters for stock and recruitment curves for West Coast Vancouver Island chum salmon. Returns and spawners are listed in Table 12. Yield and spawners are listed to the nearest thousand.

Parameter	Combined	Broodyear	
		Odd years	Even years
a	0.90	1.16	0.59
B	581	496	662
maximum sustained yield	168	199	118
optimum escapement	252	207	303
optimum exploitation rate	40%	49%	28%

Table 14. Projected returns, catches, and escapements by managing West Coast Vancouver Island chum salmon stock for an annual 45% exploitation rate. Observed returns for 1960-1964 and an age composition of 25% age 3, 70% age 4, and 5% age 5 were used. Estimates are listed to the nearest thousand.

Broodyear	Returns	Catch	Escapement
1960	1400	630	770
1961	1008	453	554
1962	976	439	536
1963	997	448	548
1964	756	340	415
1965	608	273	334
1966	717	322	394
1967	611	275	336
1968	622	280	342
1969	586	263	322
1970	535	241	294
1971	567	255	312
1972	535	240	294
1973	571	257	314
1974	501	225	275
1975	529	238	290
1976	496	223	272
1977	518	233	285
1978	485	218	266
1979	530	238	291
1980	494	222	271
1981	547	246	301
1982	507	228	279
1983	555	249	305
1984	471	212	259
1985	504	227	277
1986	514	231	282

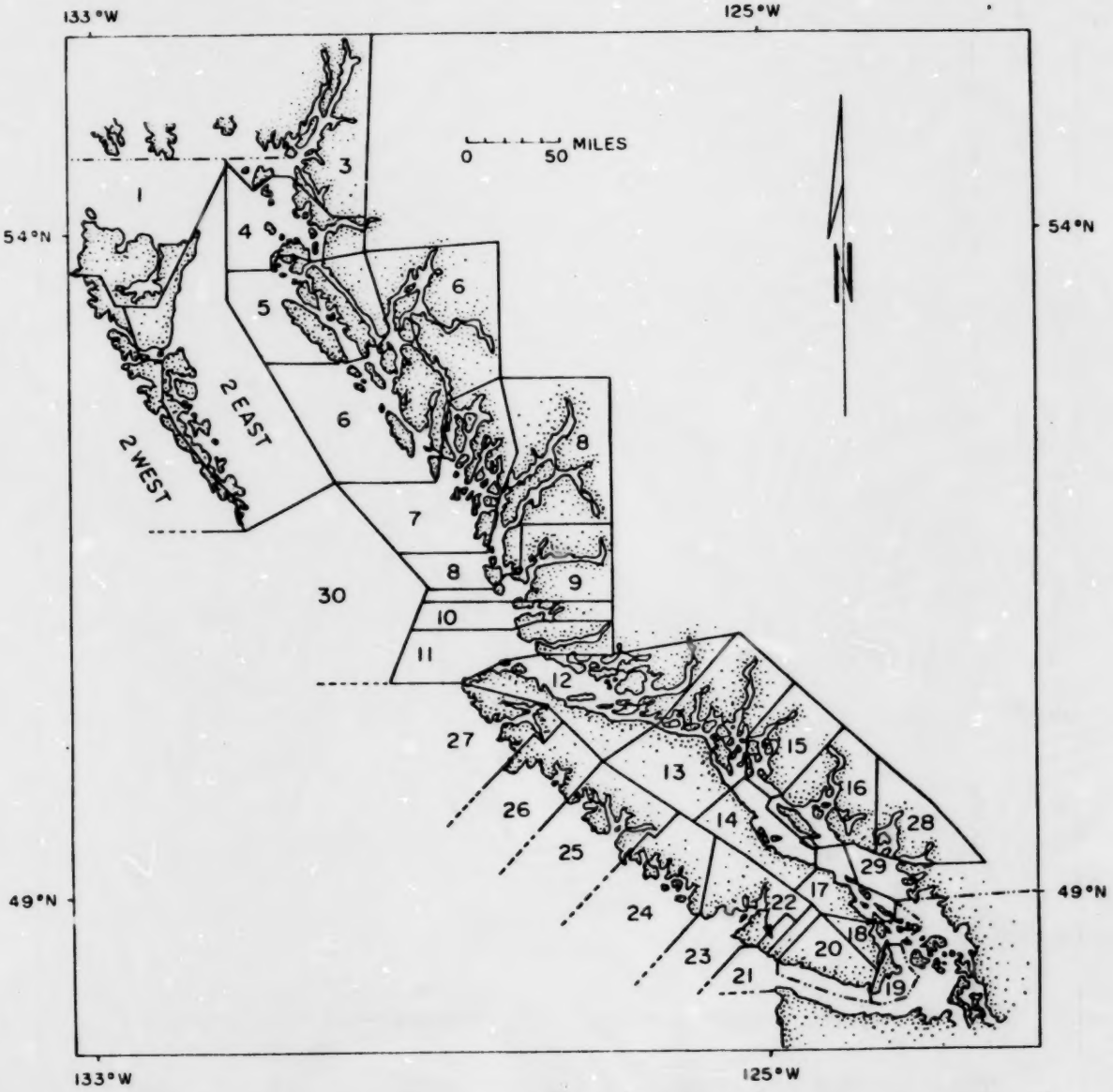

Fig. 1. Fishing statistical areas in British Columbia.

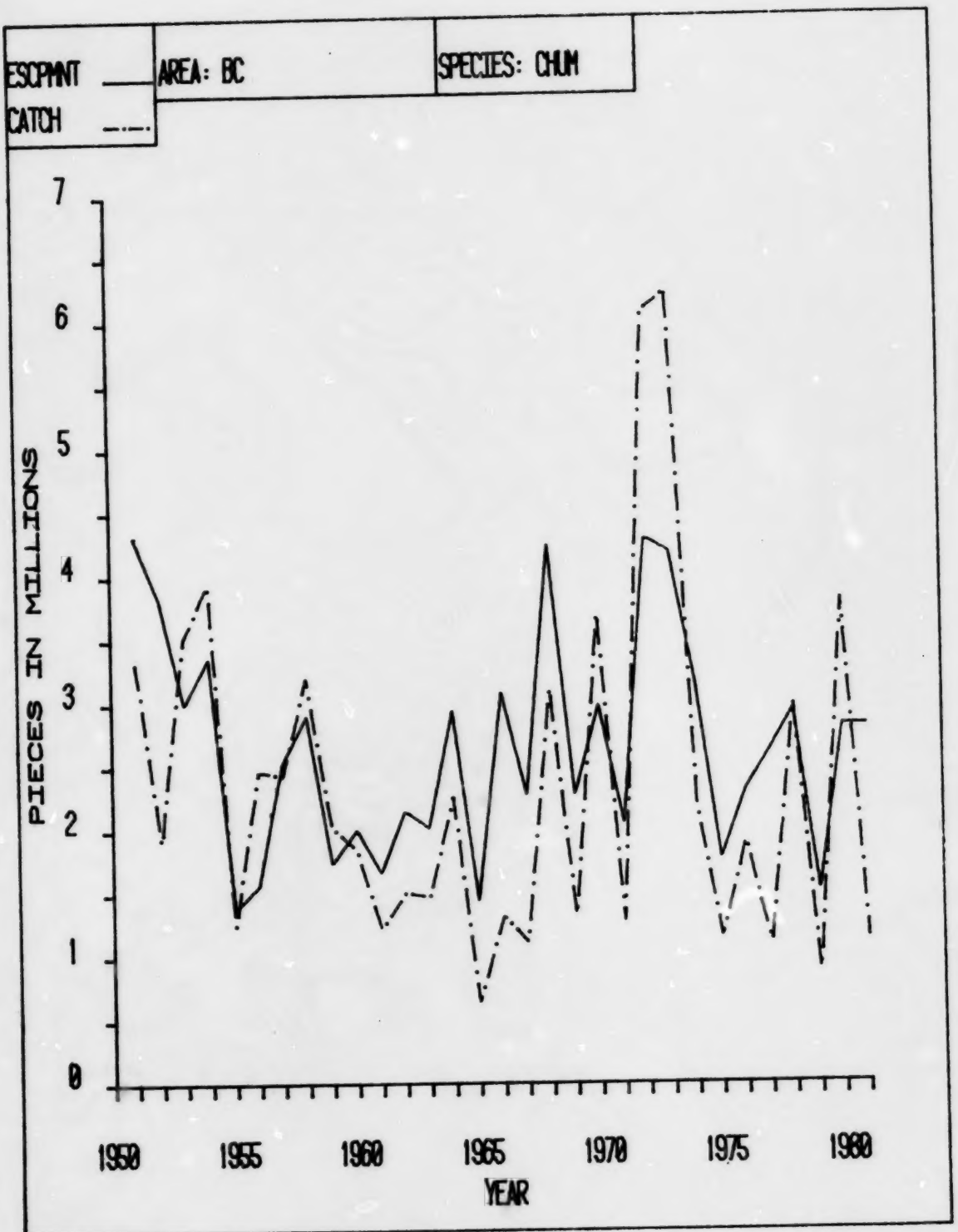

Fig. 2. Catch and escapement of British Columbia chum salmon.

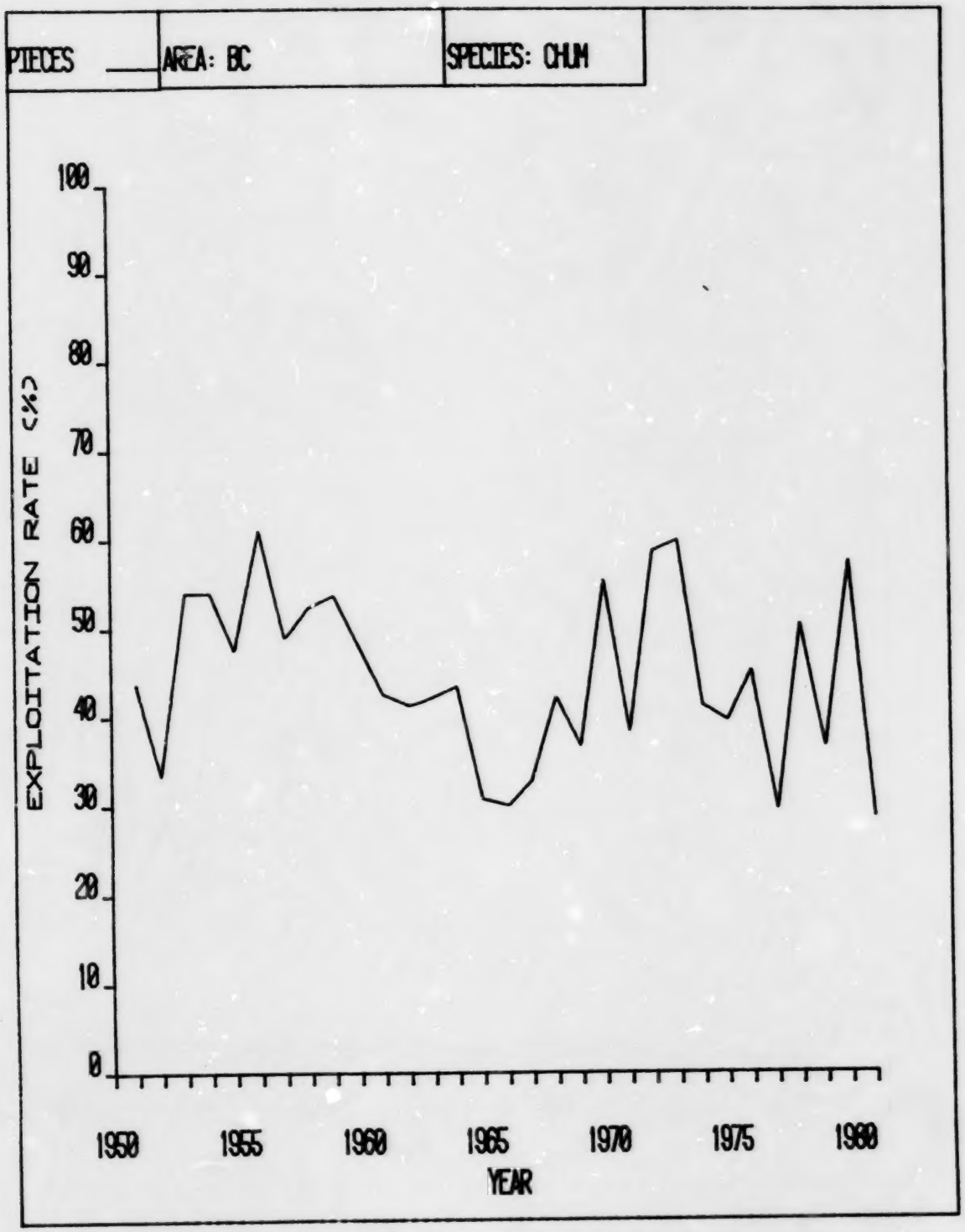

Fig. 3. Exploitation rate of British Columbia chum salmon.

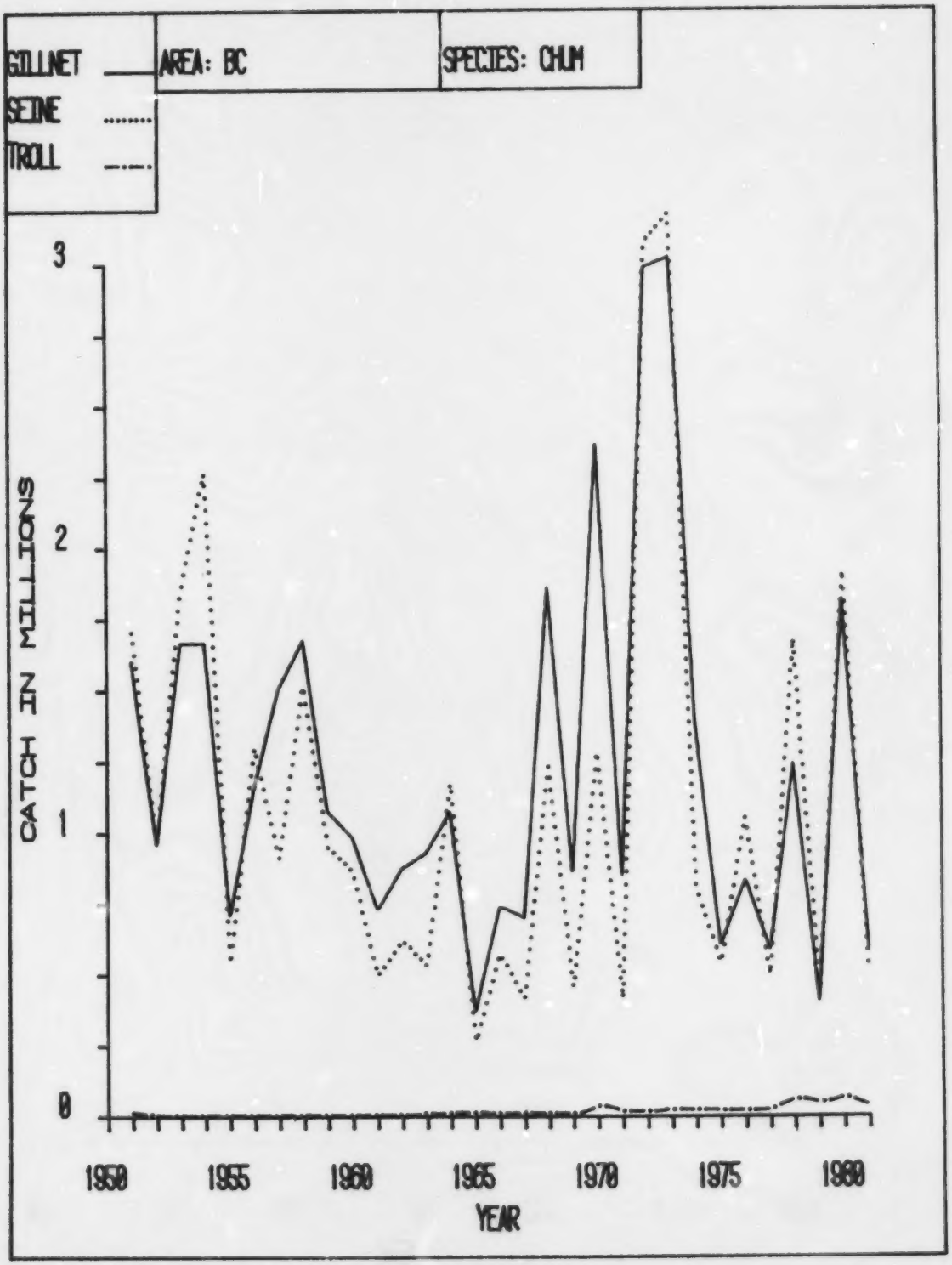

Fig. 4. Catch by gear rate of British Columbia chum salmon.

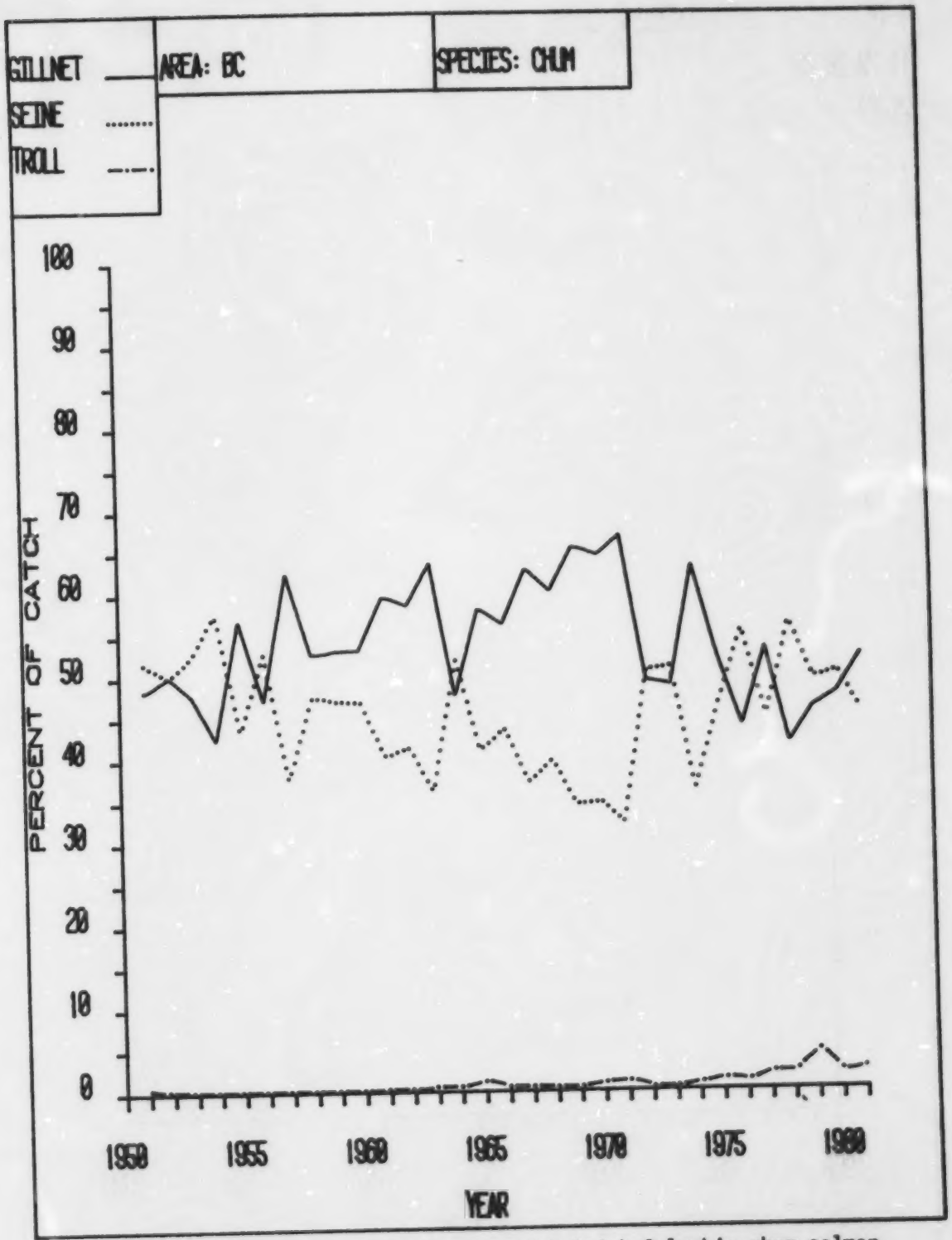

Fig. 5. Percent of total catch by gear of British Columbia chum salmon.

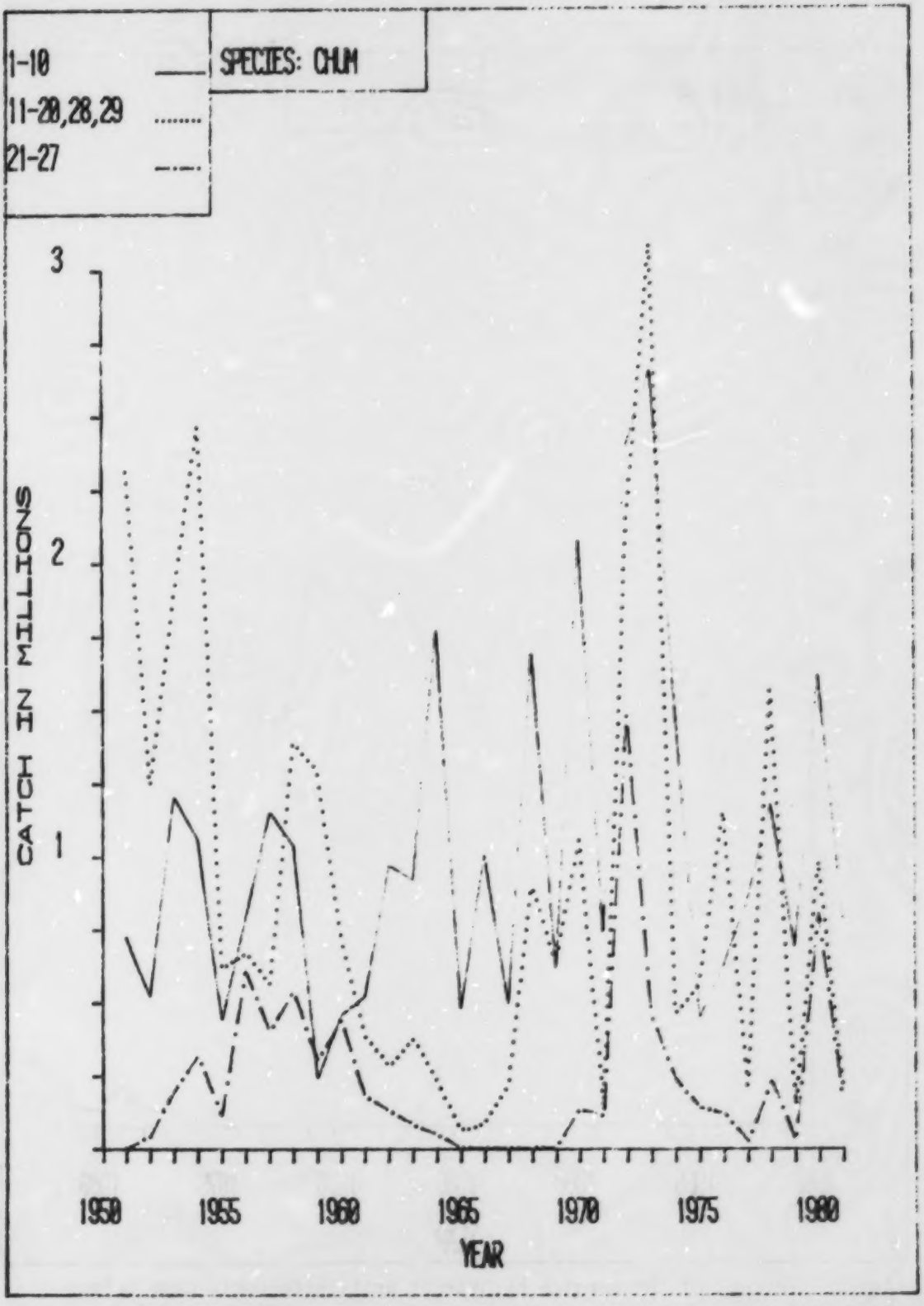

Fig. 6. Catch in northern, southern, and west coast of Vancouver Island regions of chum salmon.

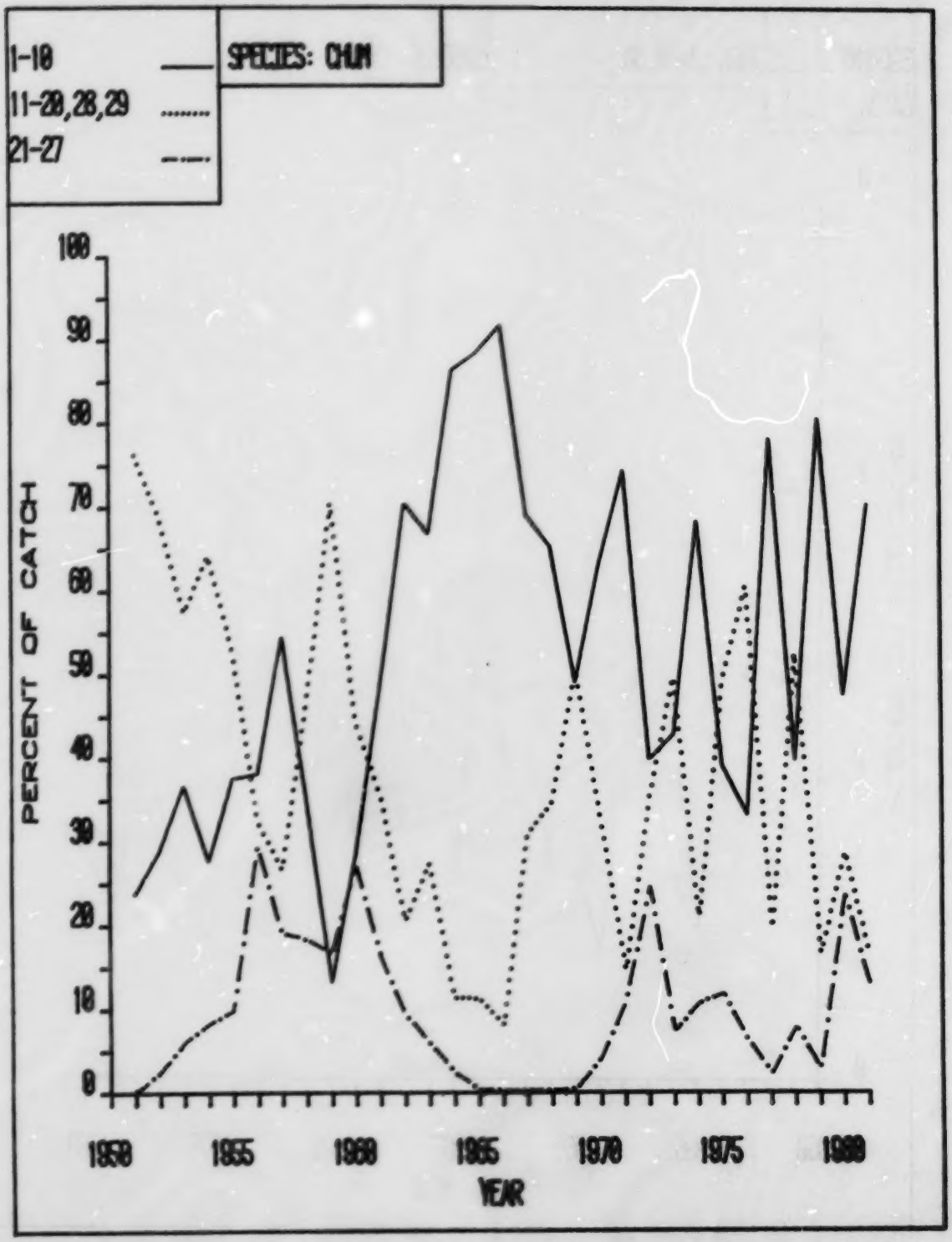

Fig. 7. Percent of total British Columbia catch by major fishery region.

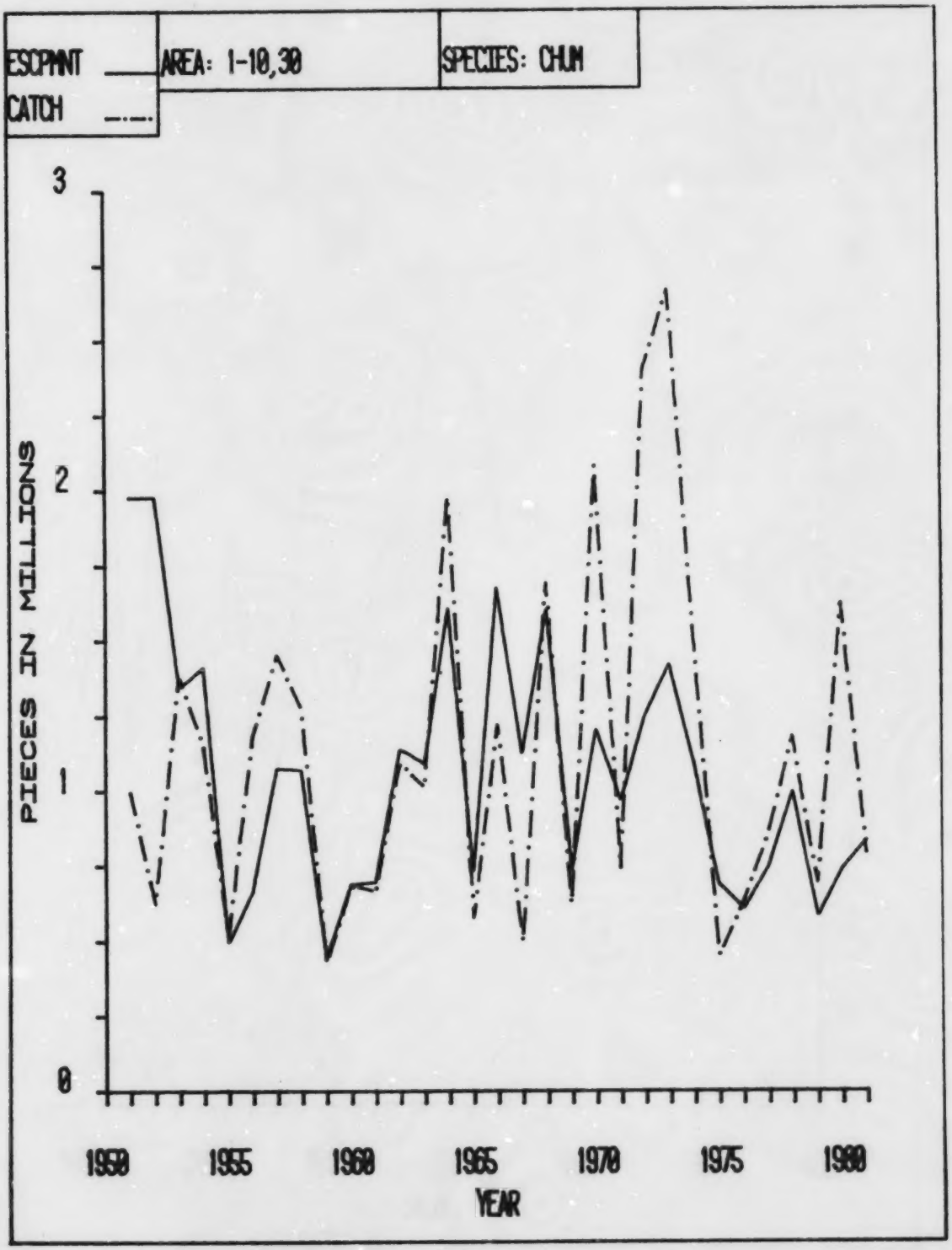

Fig. 8. Catch and escapement of North and Central Coast chum salmon.

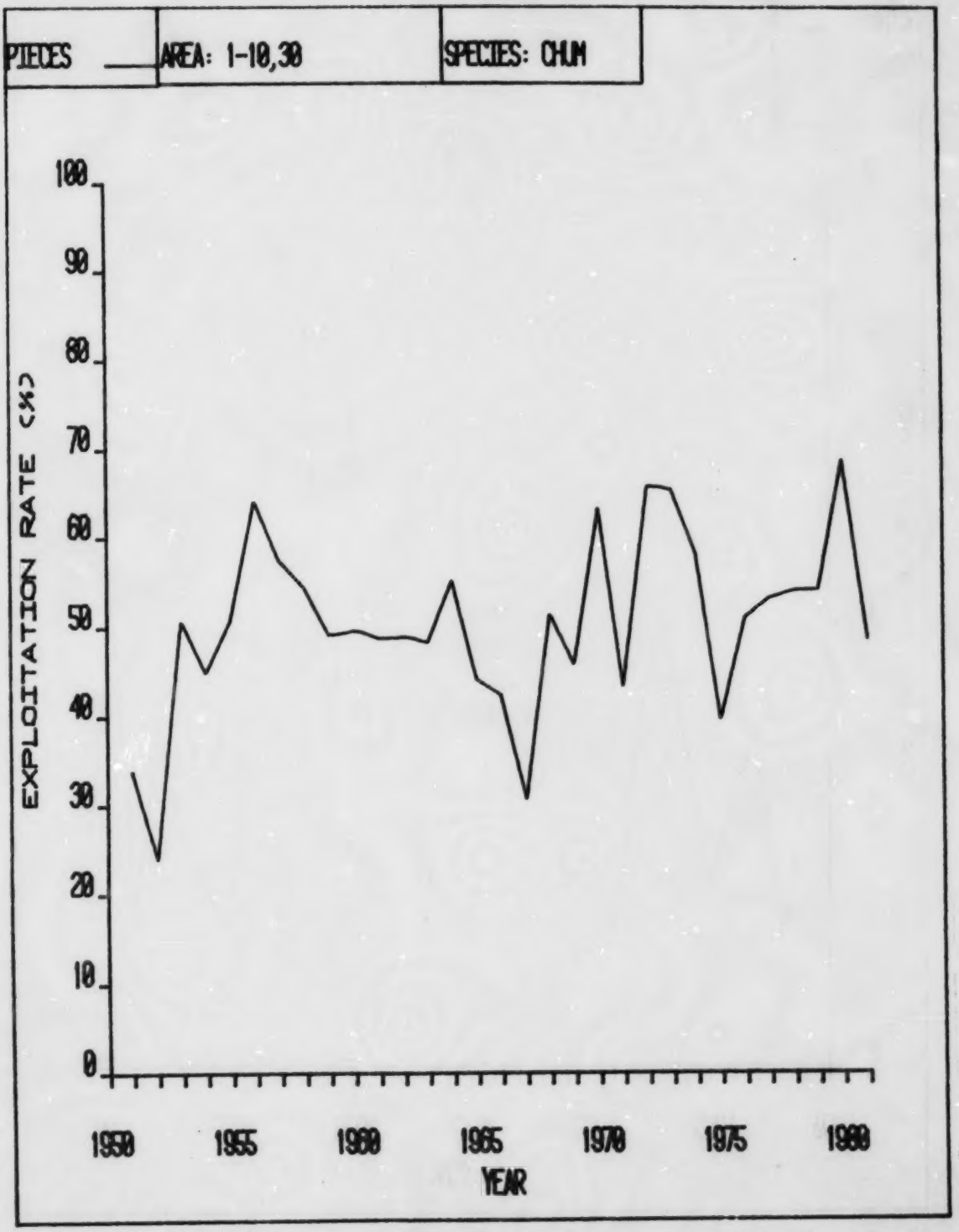

Fig. 9. Exploitation rate of North and Central Coast chum salmon.

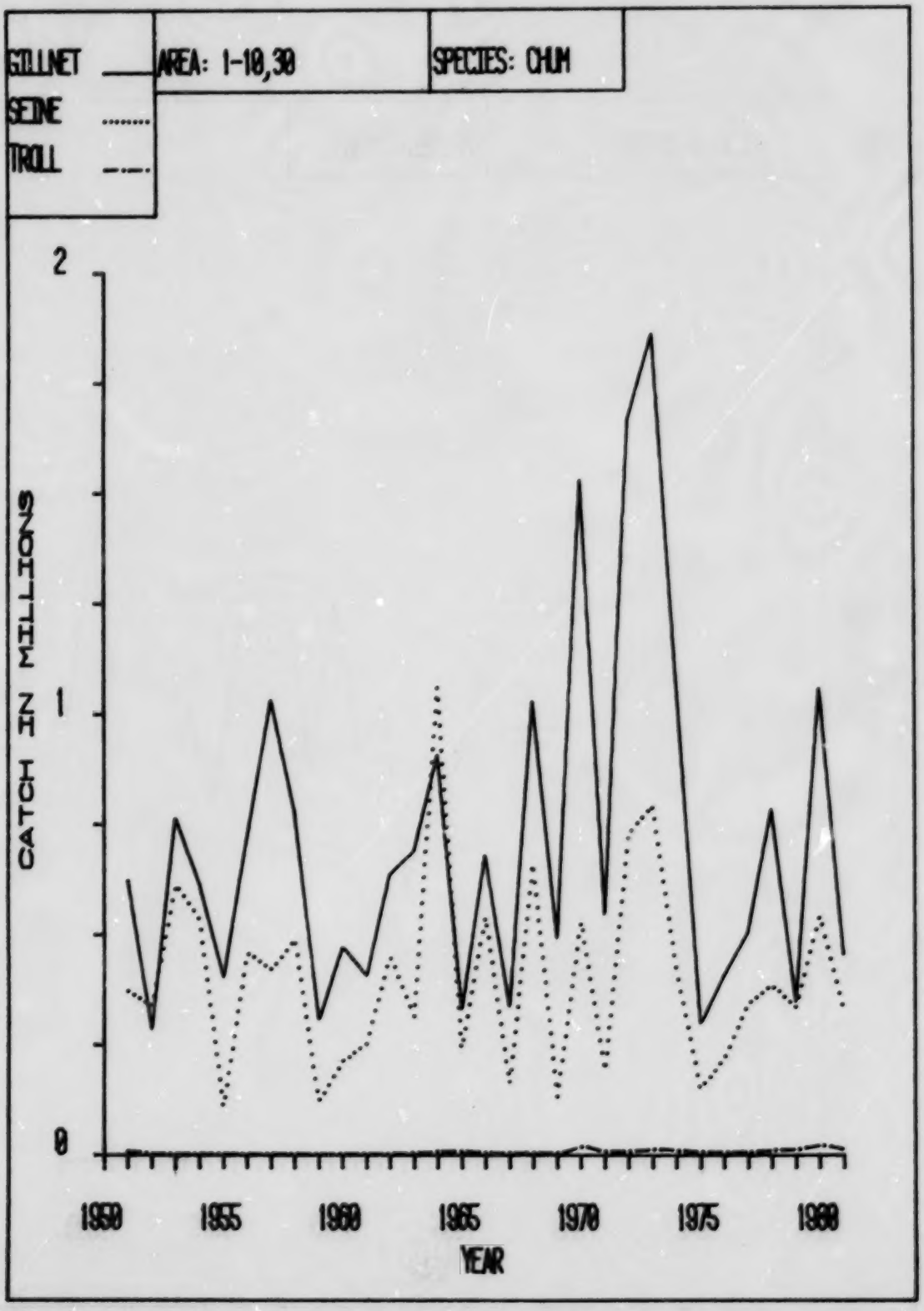

Fig. 10. Catch by gear of North and Central Coast chum salmon.

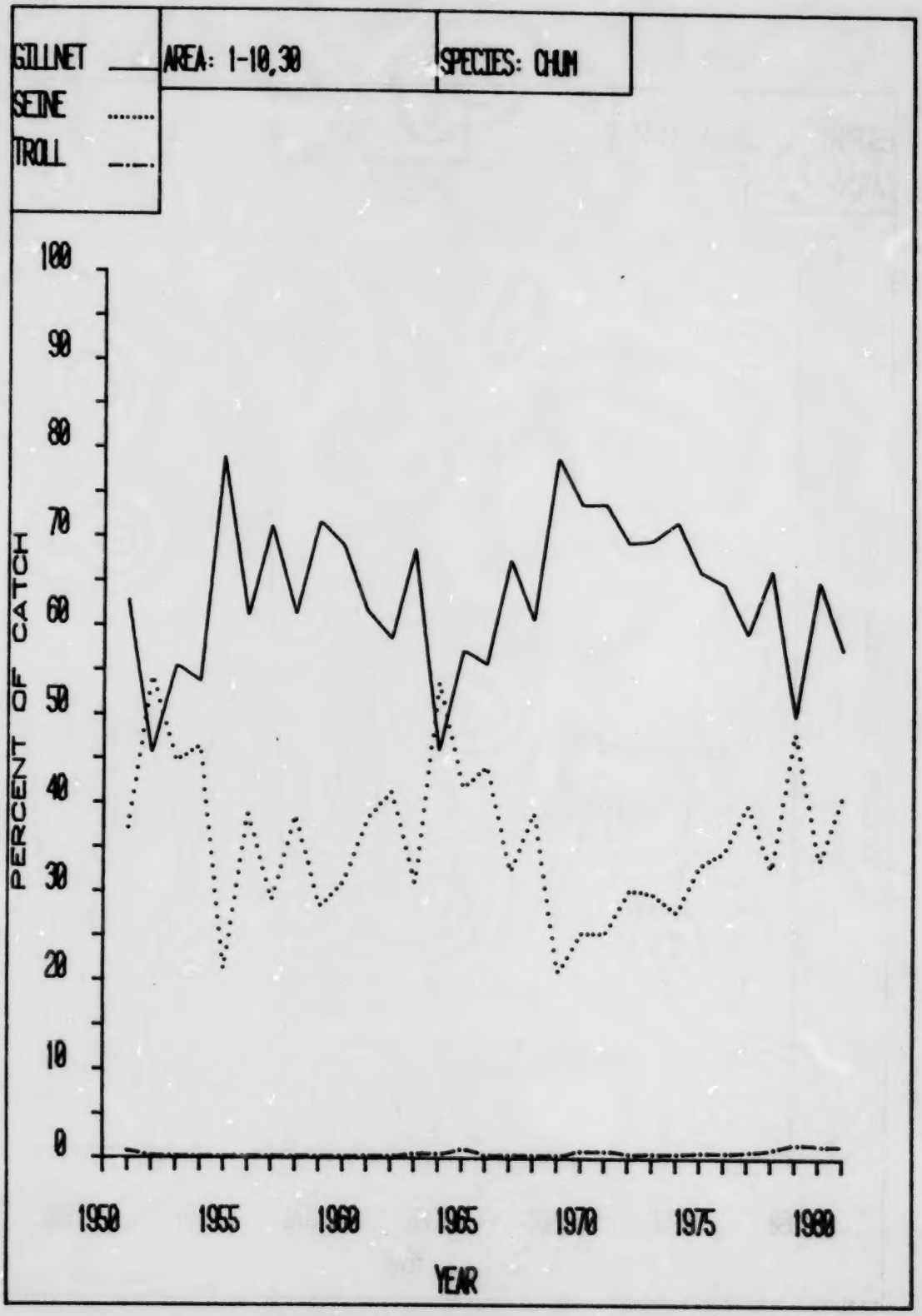

Fig. 11. Percent of total catch by hear of North and Central Coast chum salmon.

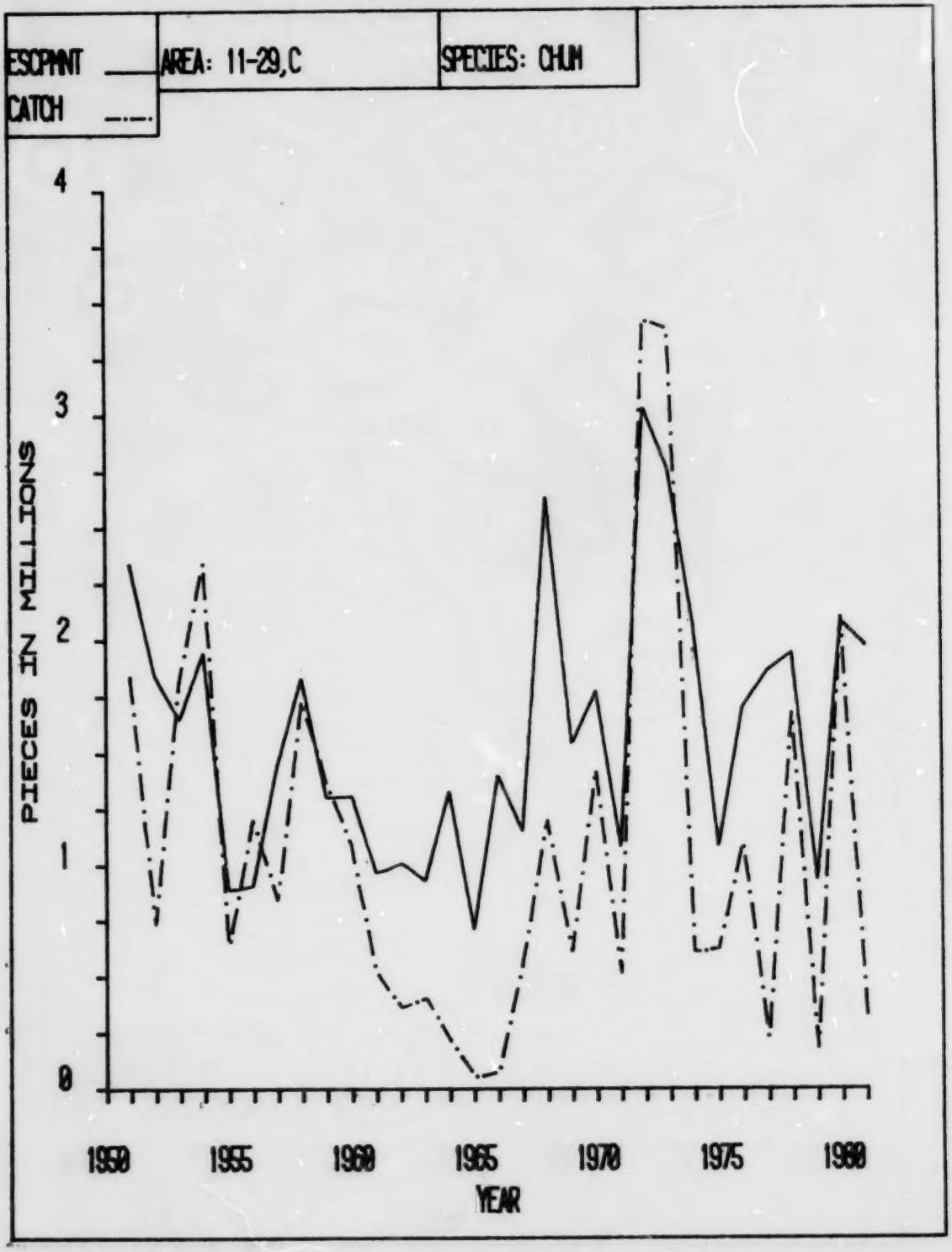

Fig. 12. Catch and escapement of South Coast and Fraser River chum salmon.

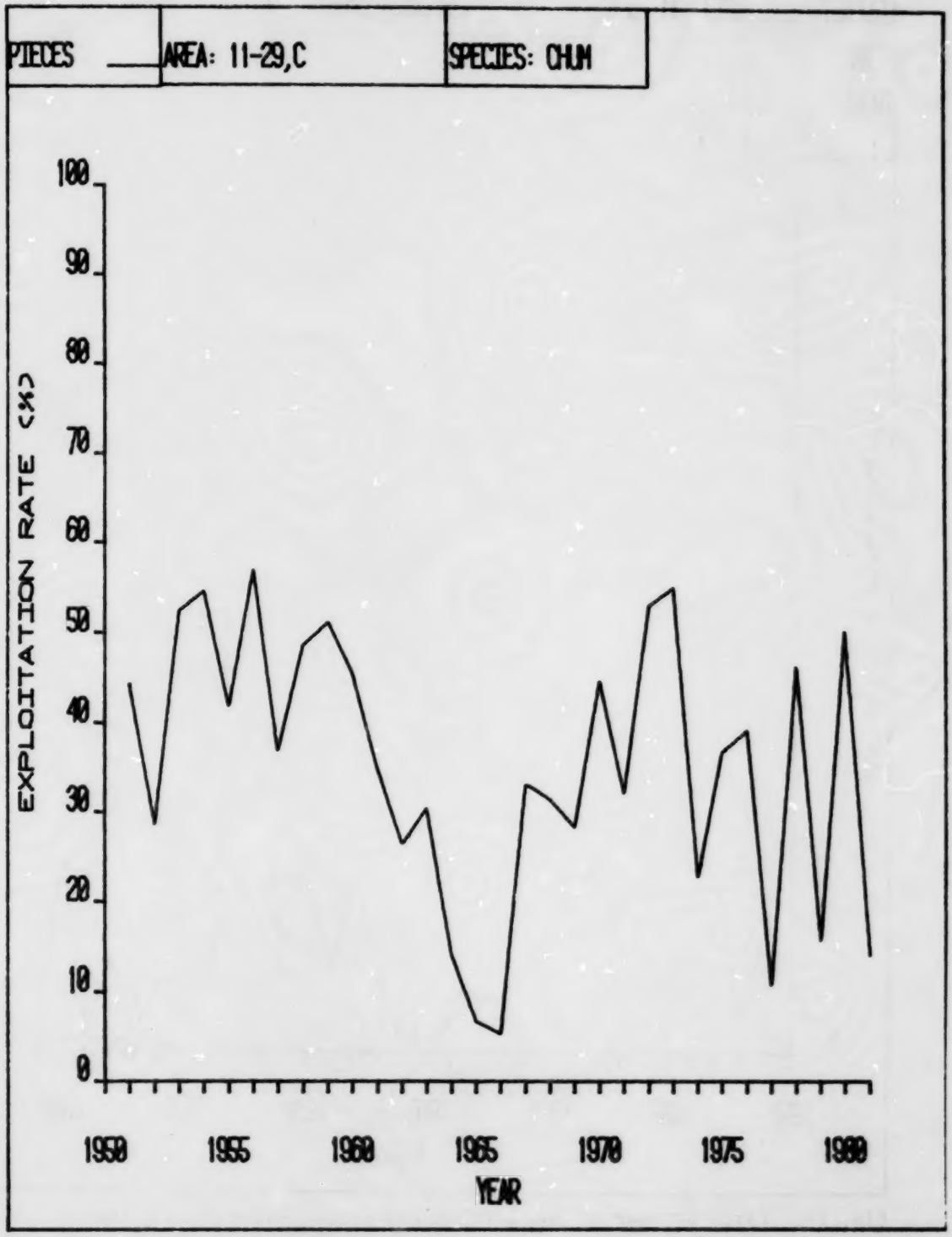

Fig. 13. Exploitation rate of South Coast and Fraser River chum salmon.

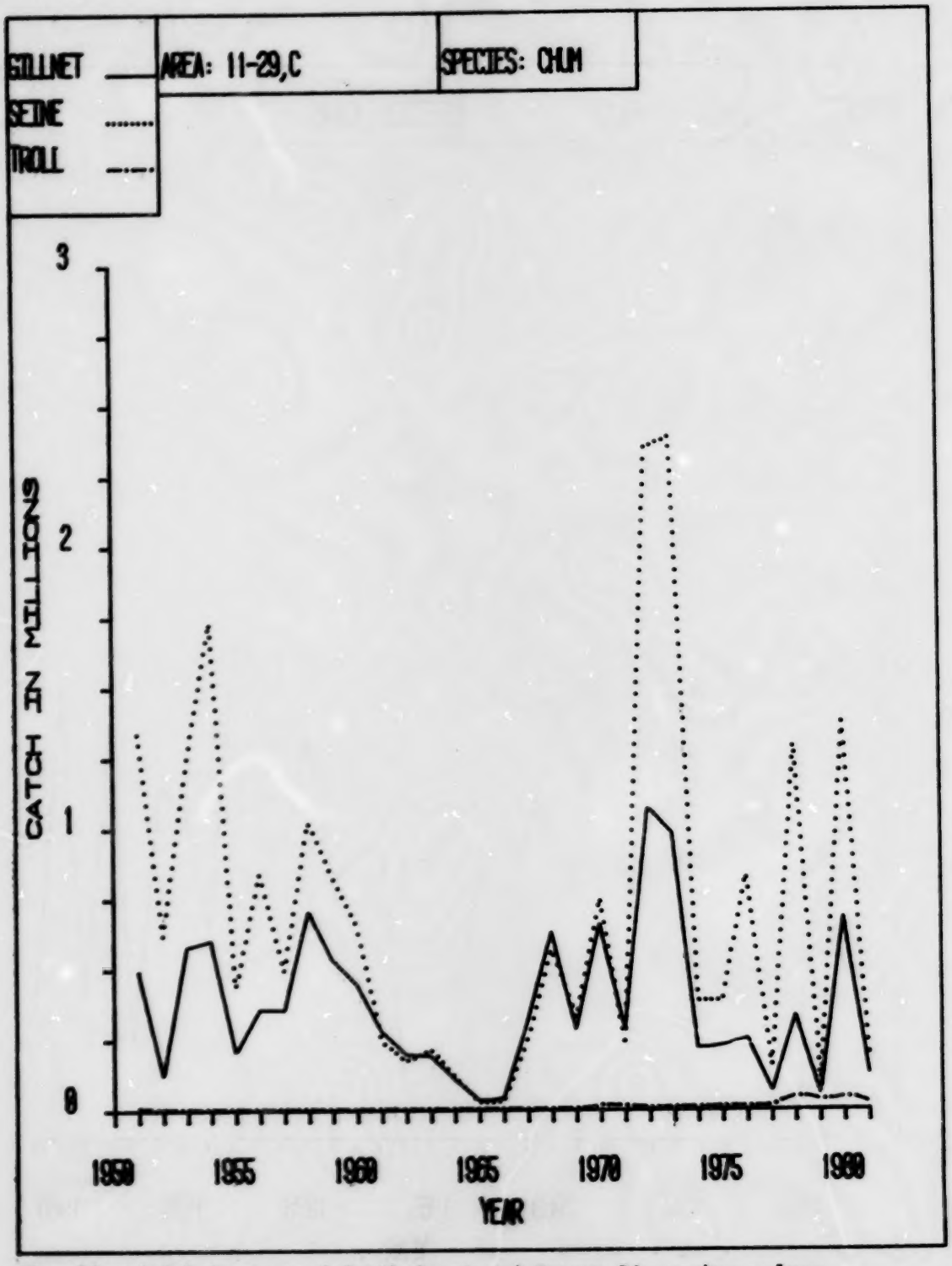

Fig. 14. Catch by gear of South Coast and Fraser River chum salmon.

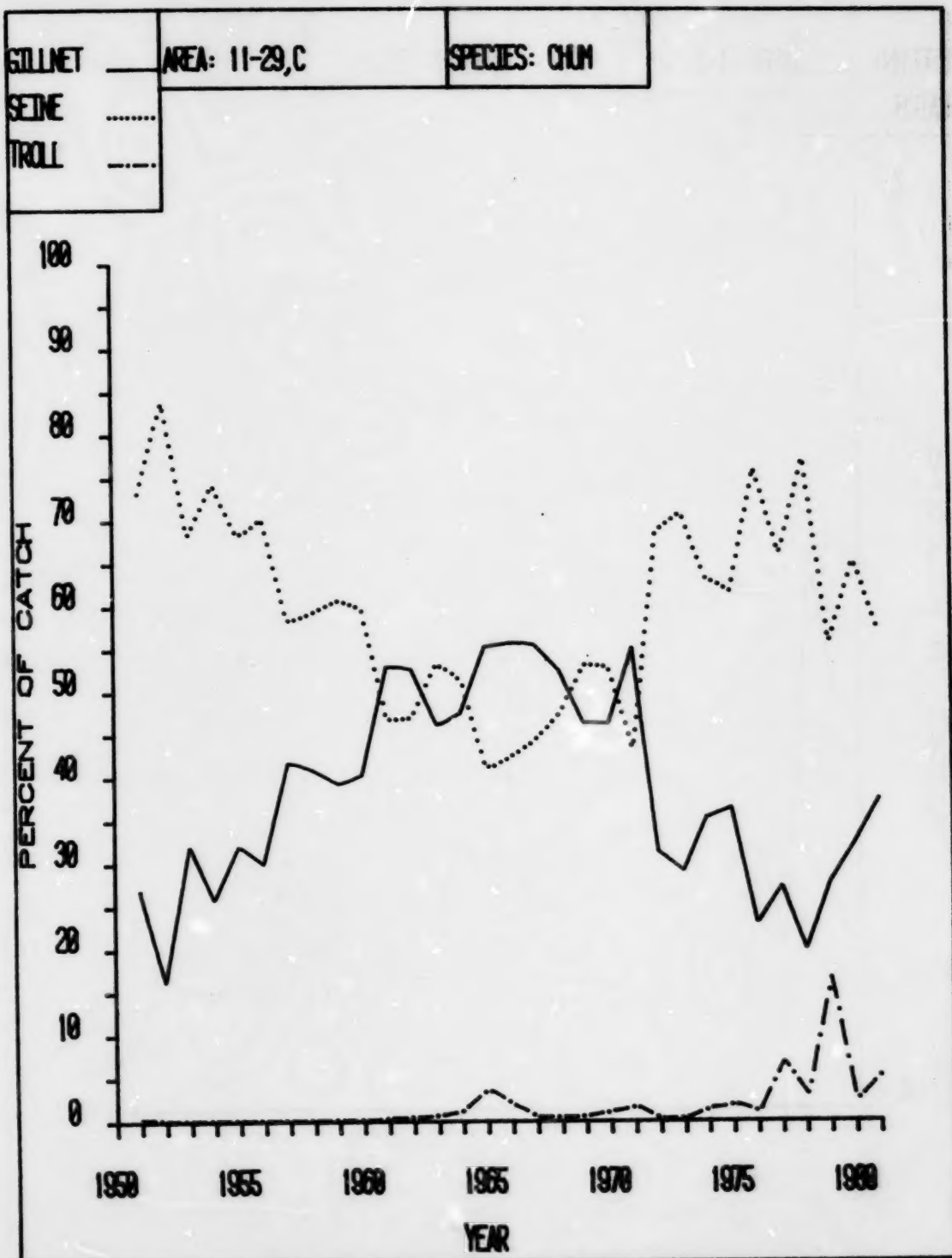

Fig. 15. Percent of total catch by gear of South Coast and Fraser River chum salmon.

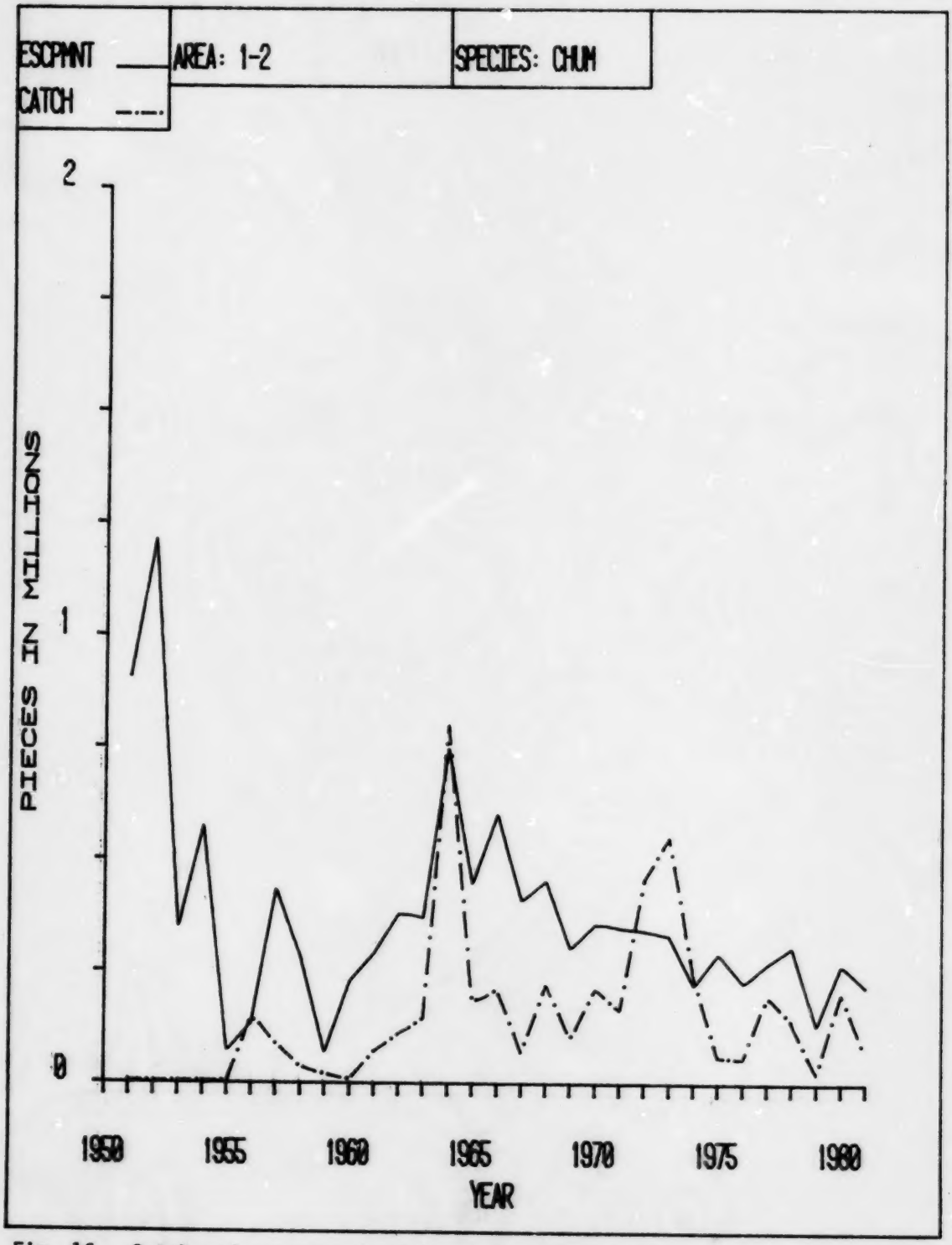

Fig. 16. Catch and escapement of Queen Charlotte Islands chum salmon.

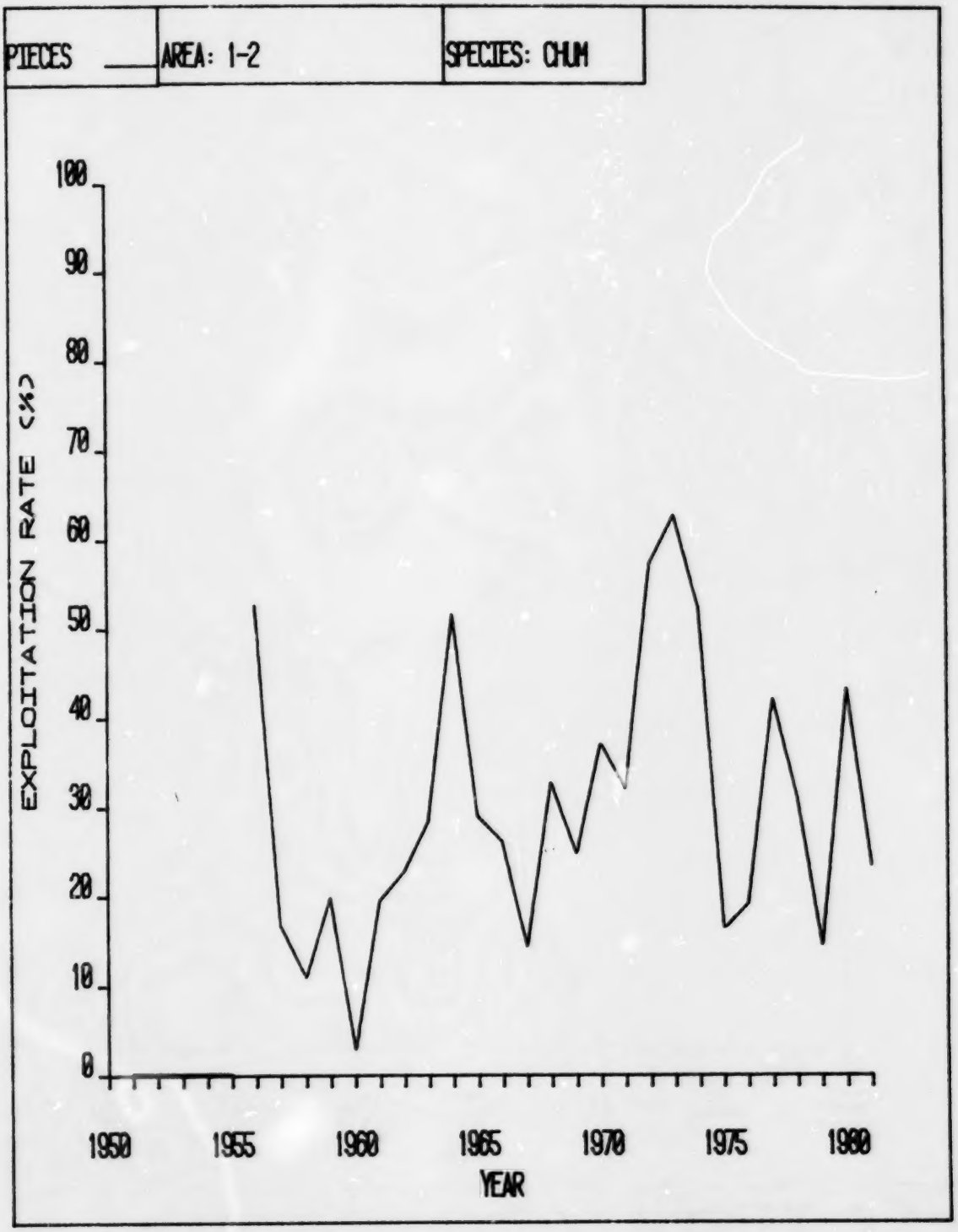

Fig. 17. Exploitation rate of Queen Charlotte Islands chum salmon.

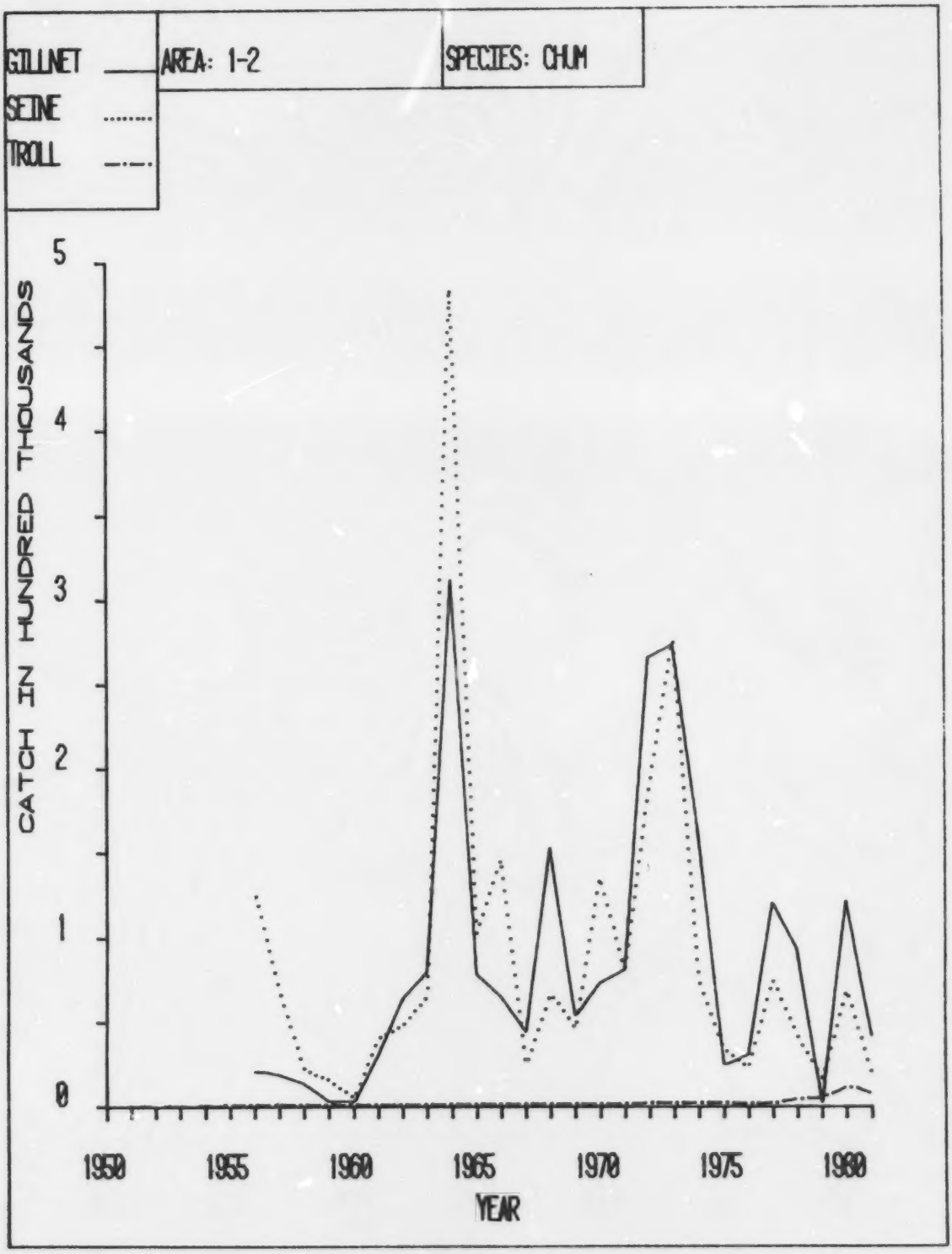

Fig. 18. Catch by gear of Queen Charlotte Islands chum salmon.

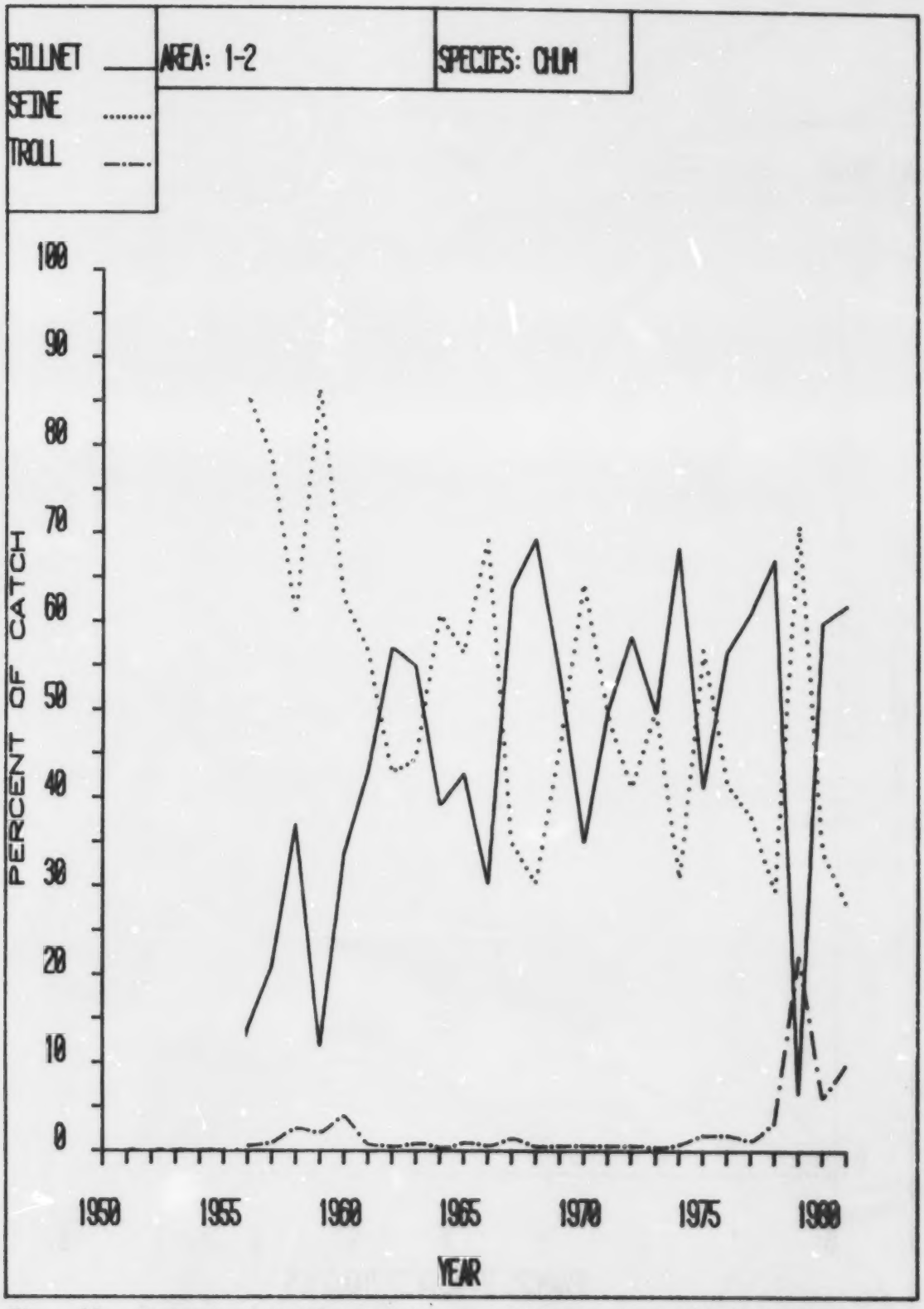

Fig. 19. Percent of total catch by gear of Queen Charlotte Islands chum salmon.

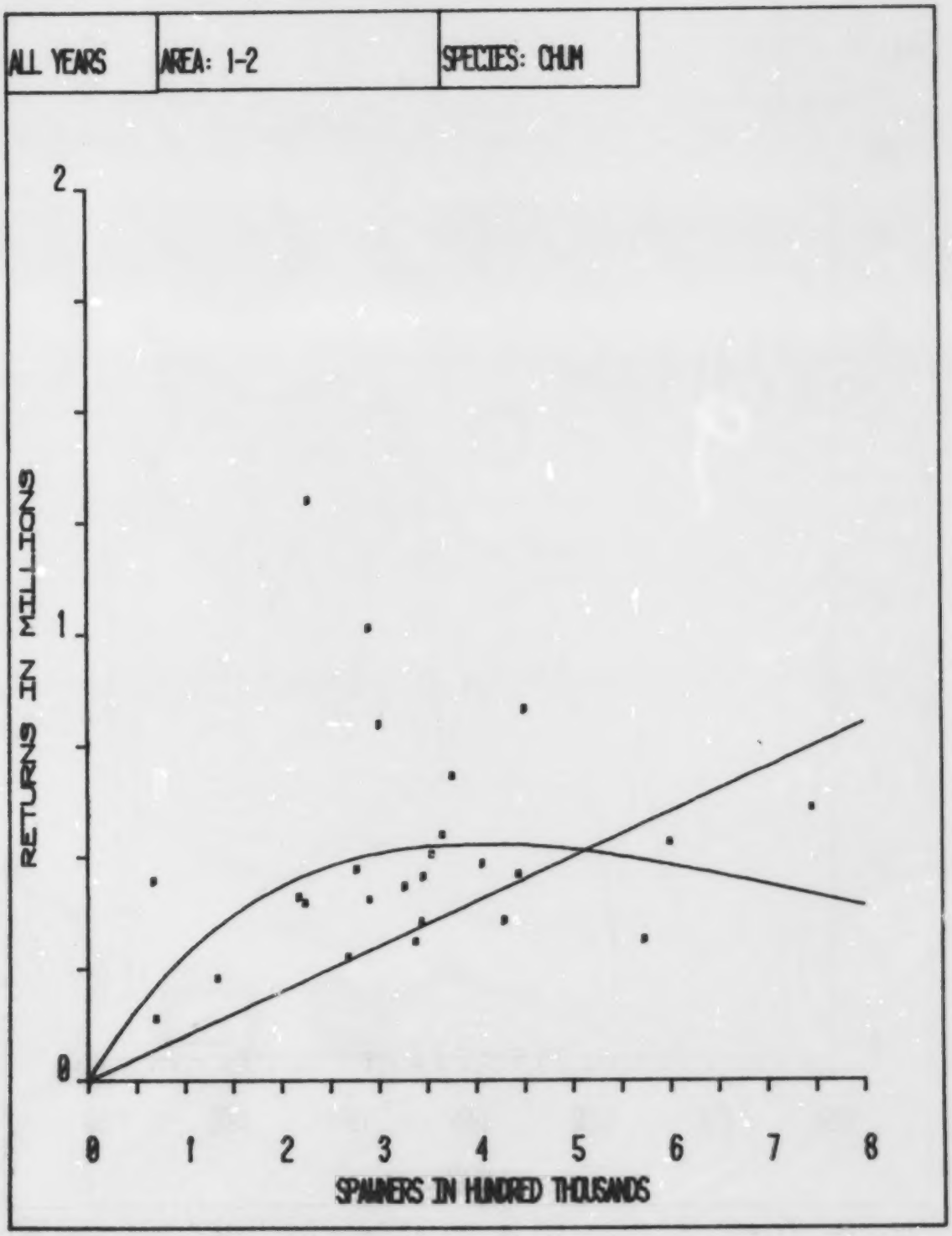

Fig. 20. Stock and recruitment curves for 1953-1977 broodyears of Queen Charlotte Islands chum salmon.

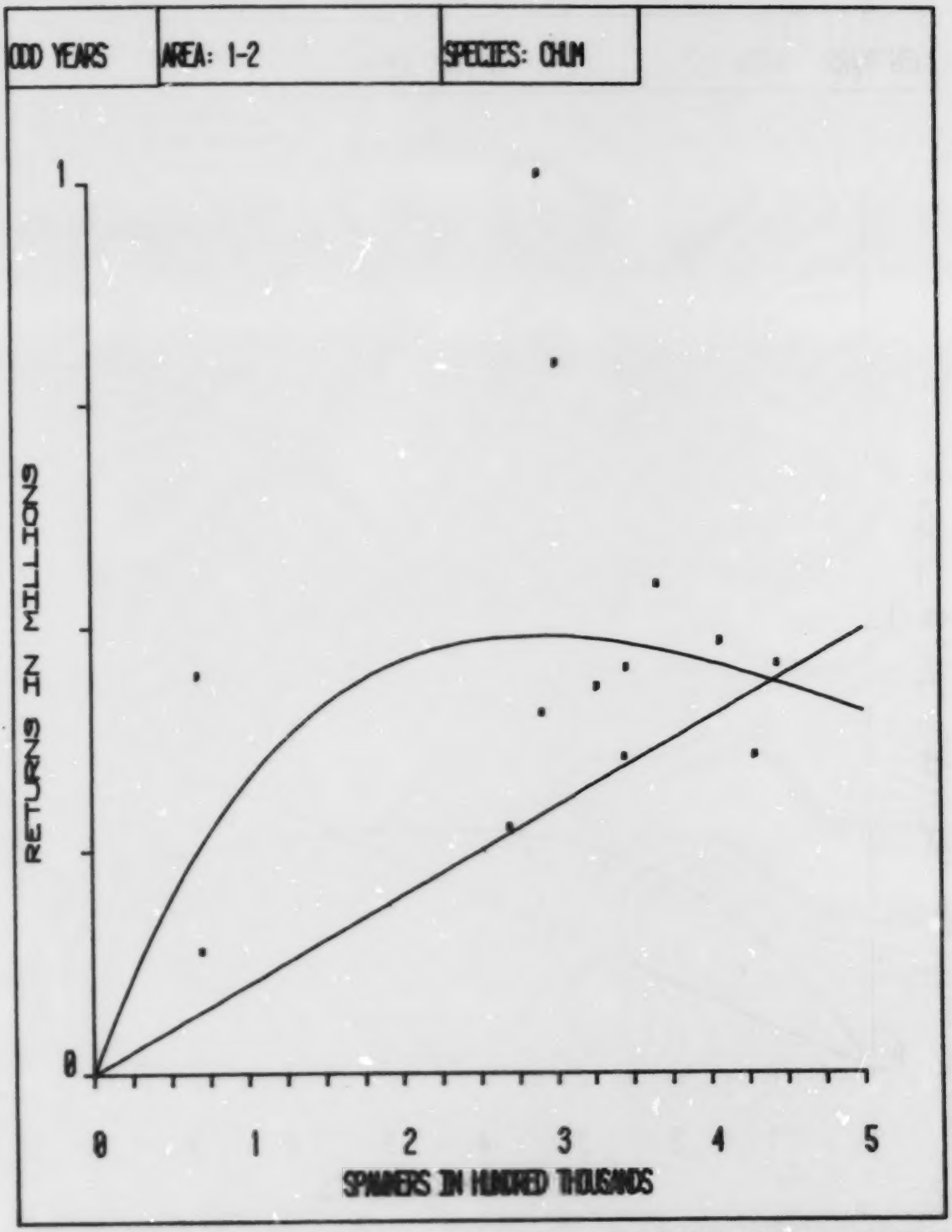

Fig. 21. Stock and recruitment for odd broodyears 1953-1977 of Queen Charlotte Islands chum salmon.

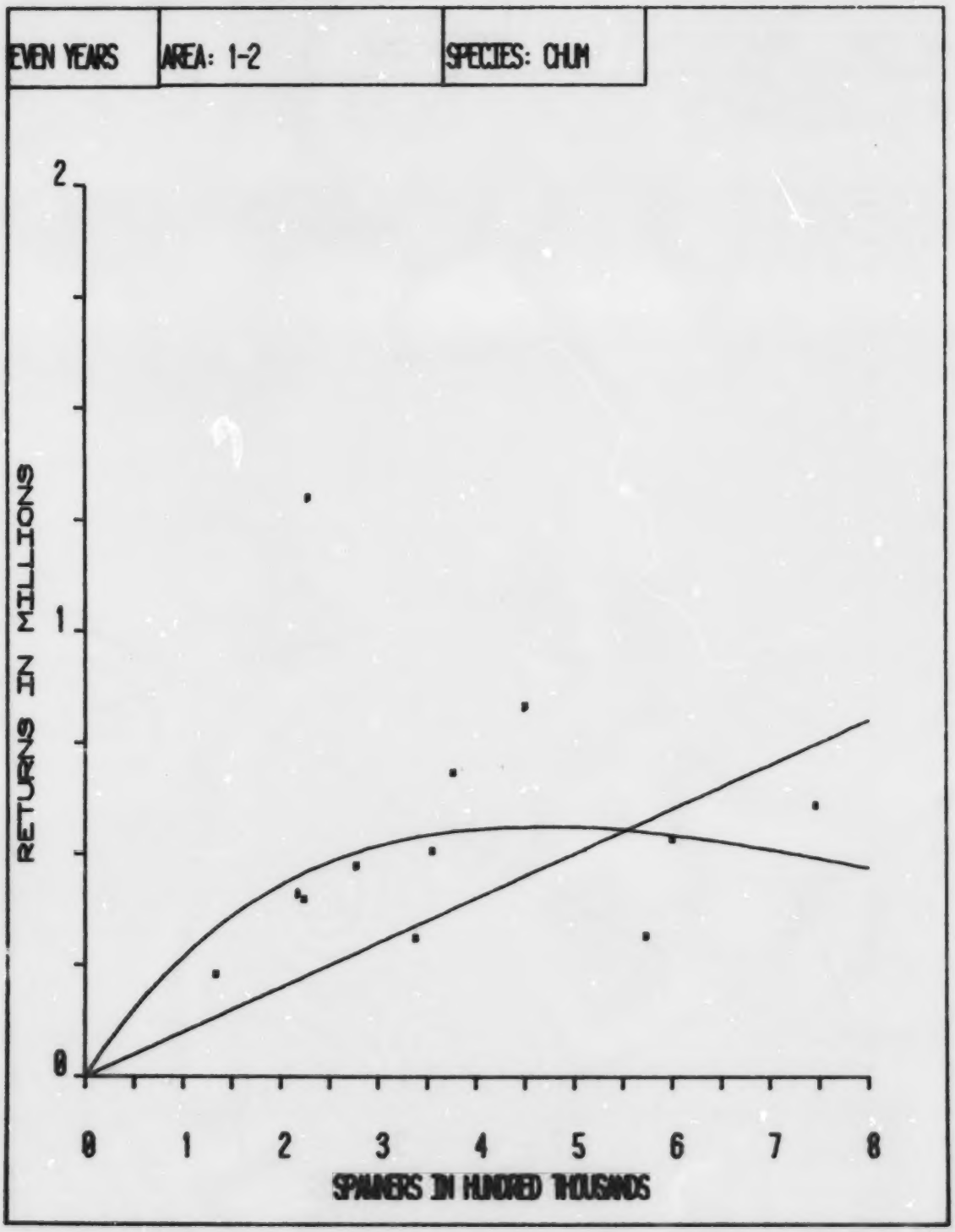

Fig. 22. Stock and recruitment for even broodyears 1954-1976 of Queen Charlotte Islands chum salmon.

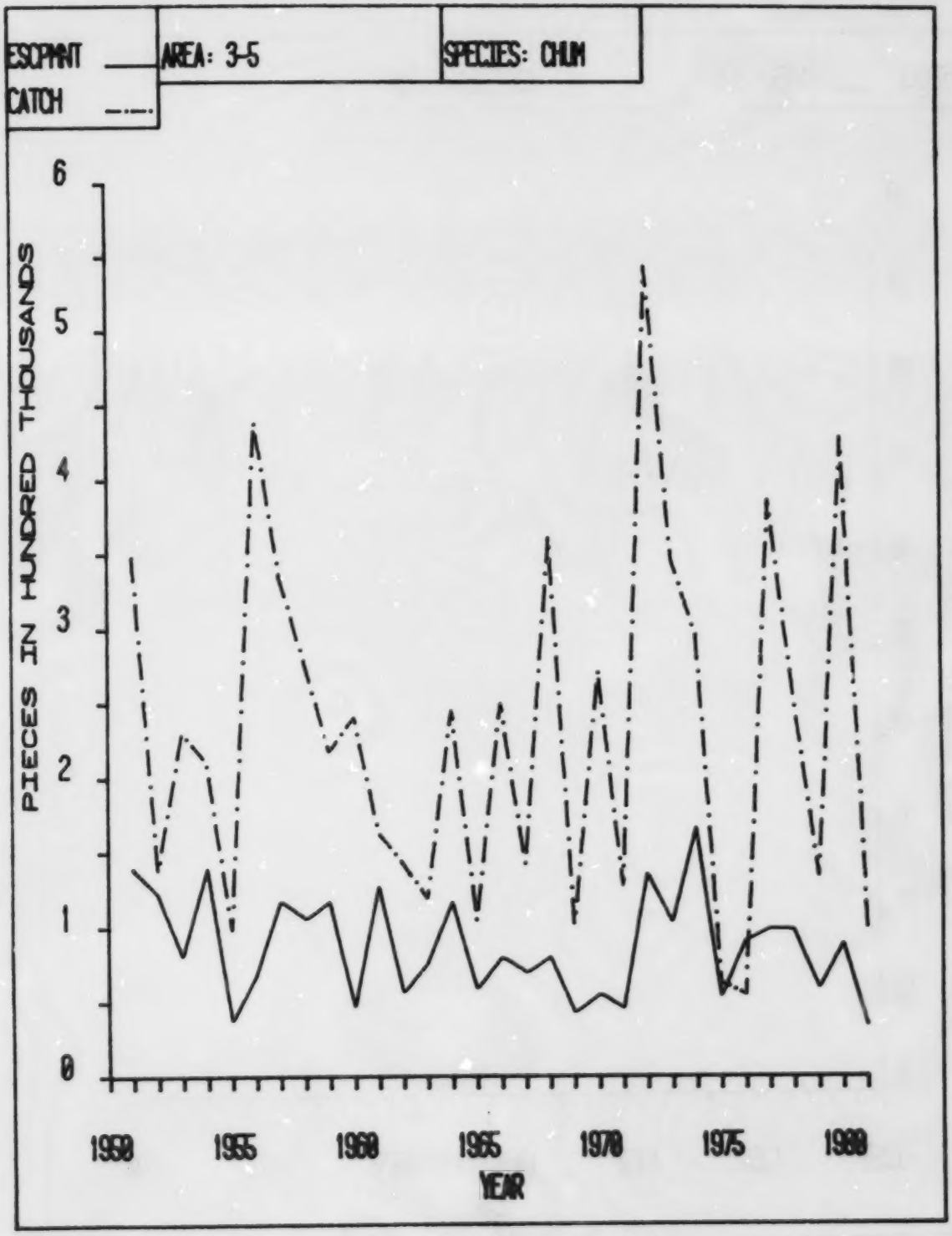

Fig. 23. Catch and escapement of North Coast chum salmon.

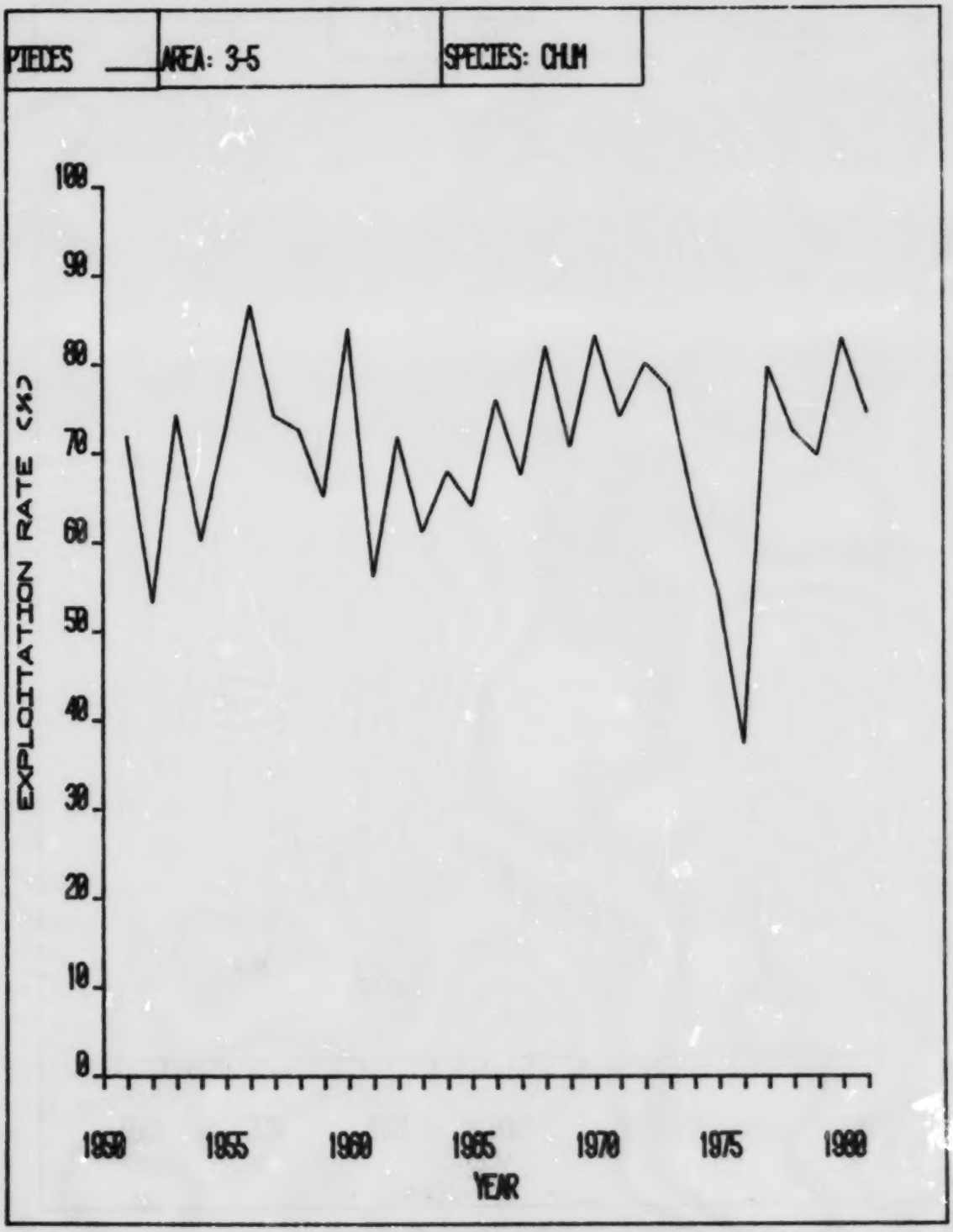

Fig. 24. Exploitation rates of North Coast chum salmon.

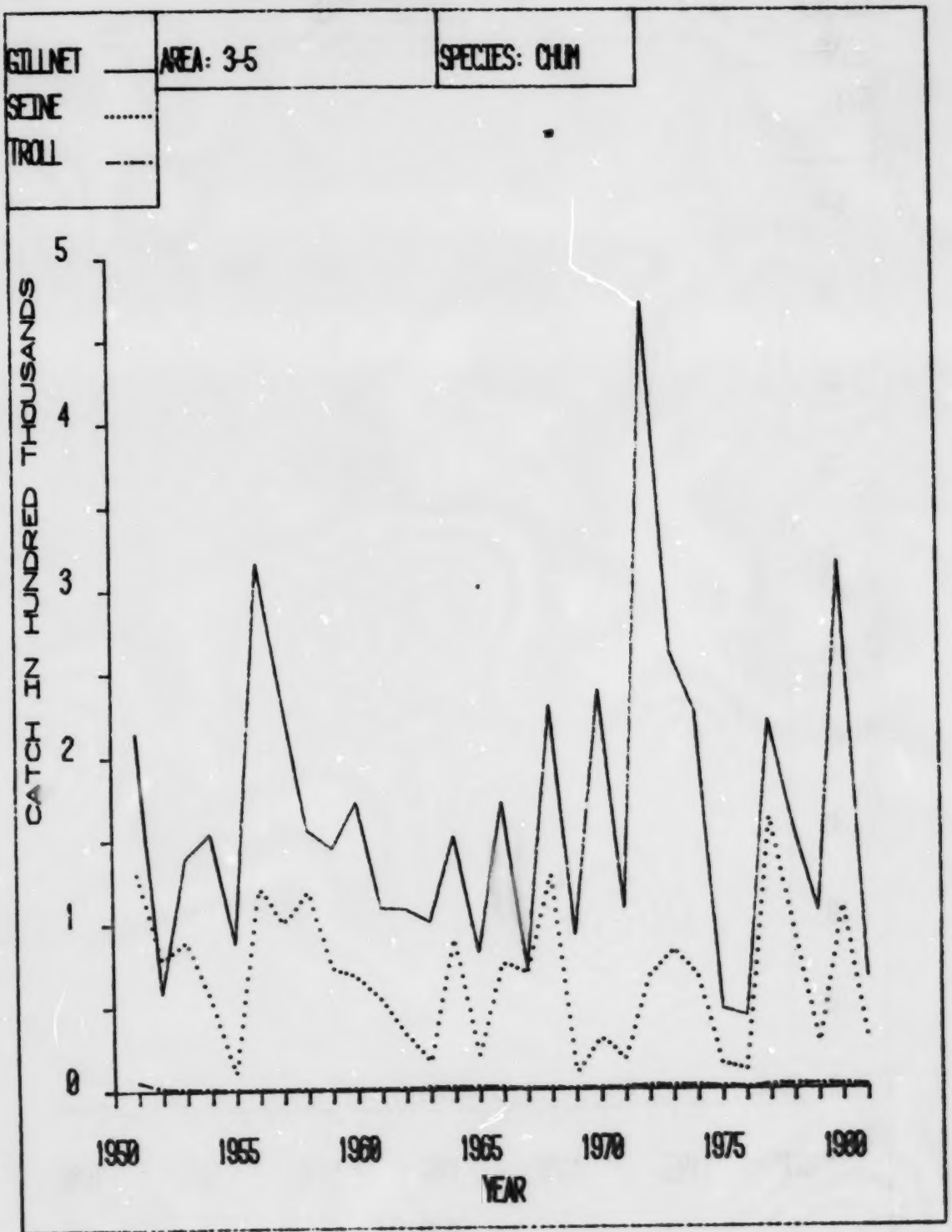

Fig. 25. Catch by gear of North Coast chum salmon.

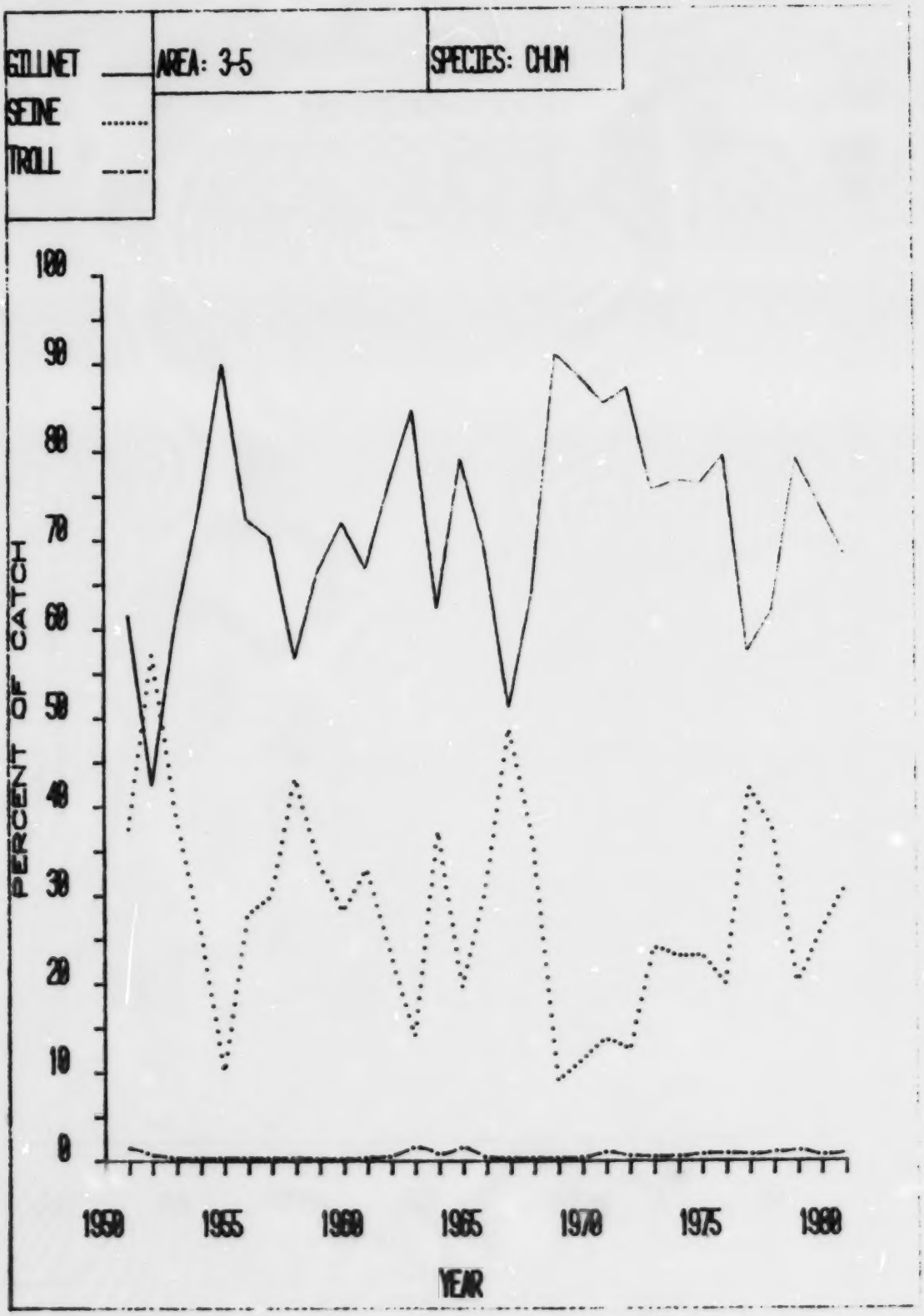

Fig. 26. Percent of total catch by gear of North Coast chum salmon.

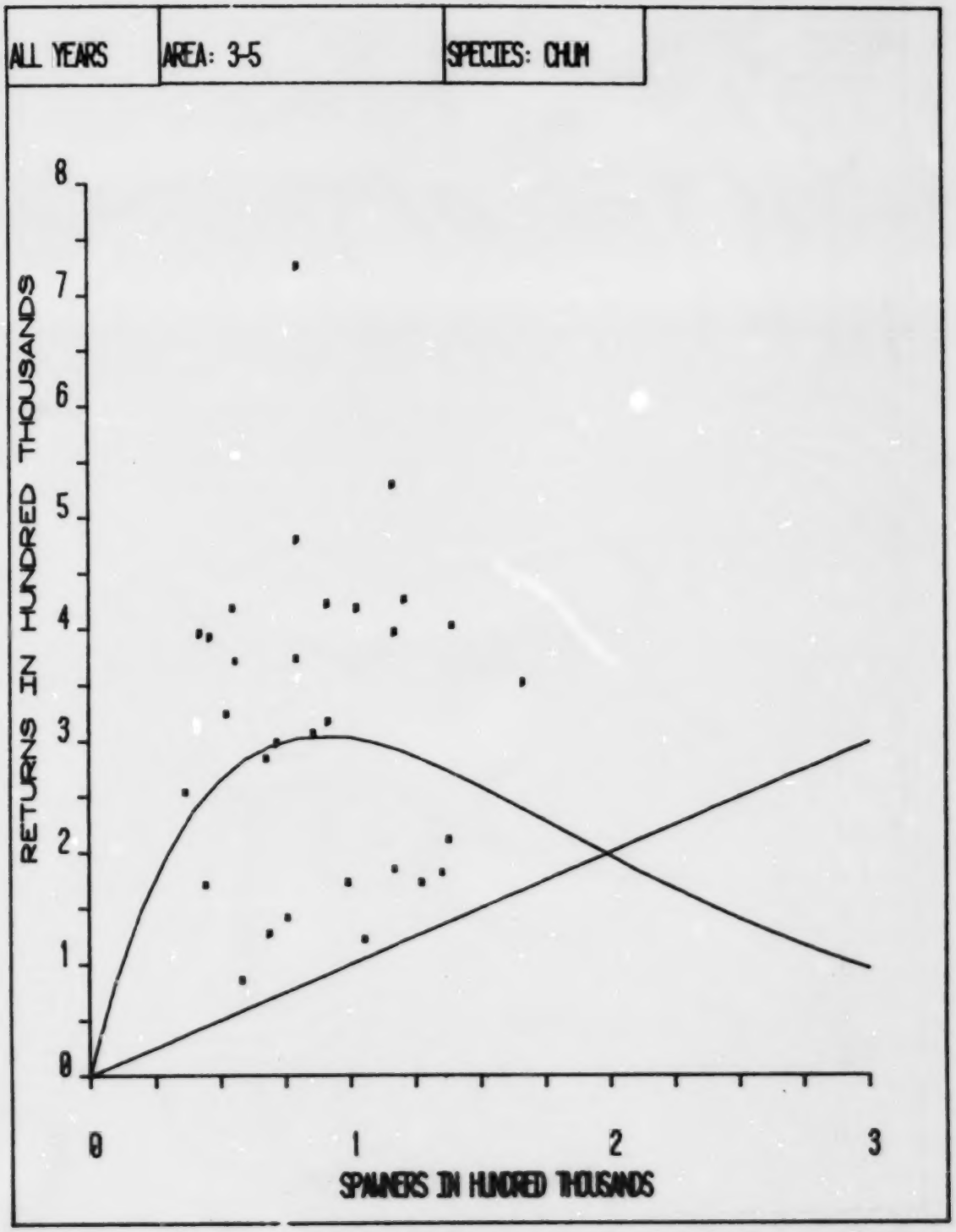

Fig. 27. Stock and recruitment curves for 1948-1977 broodyears of North Coast chum salmon.

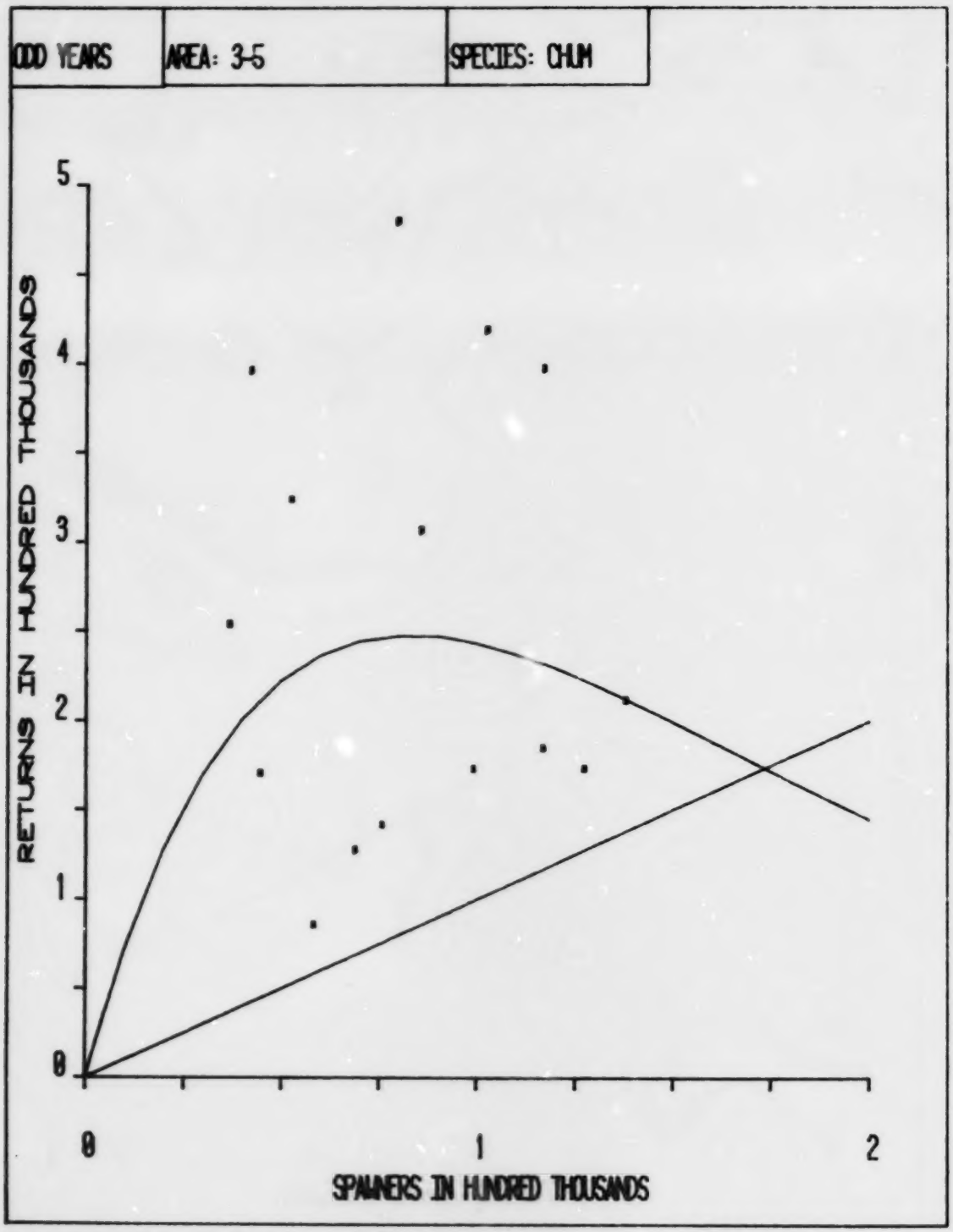

Fig. 28. Stock and recruitment curves for odd broodyears 1949-1977 of North Coast chum salmon.

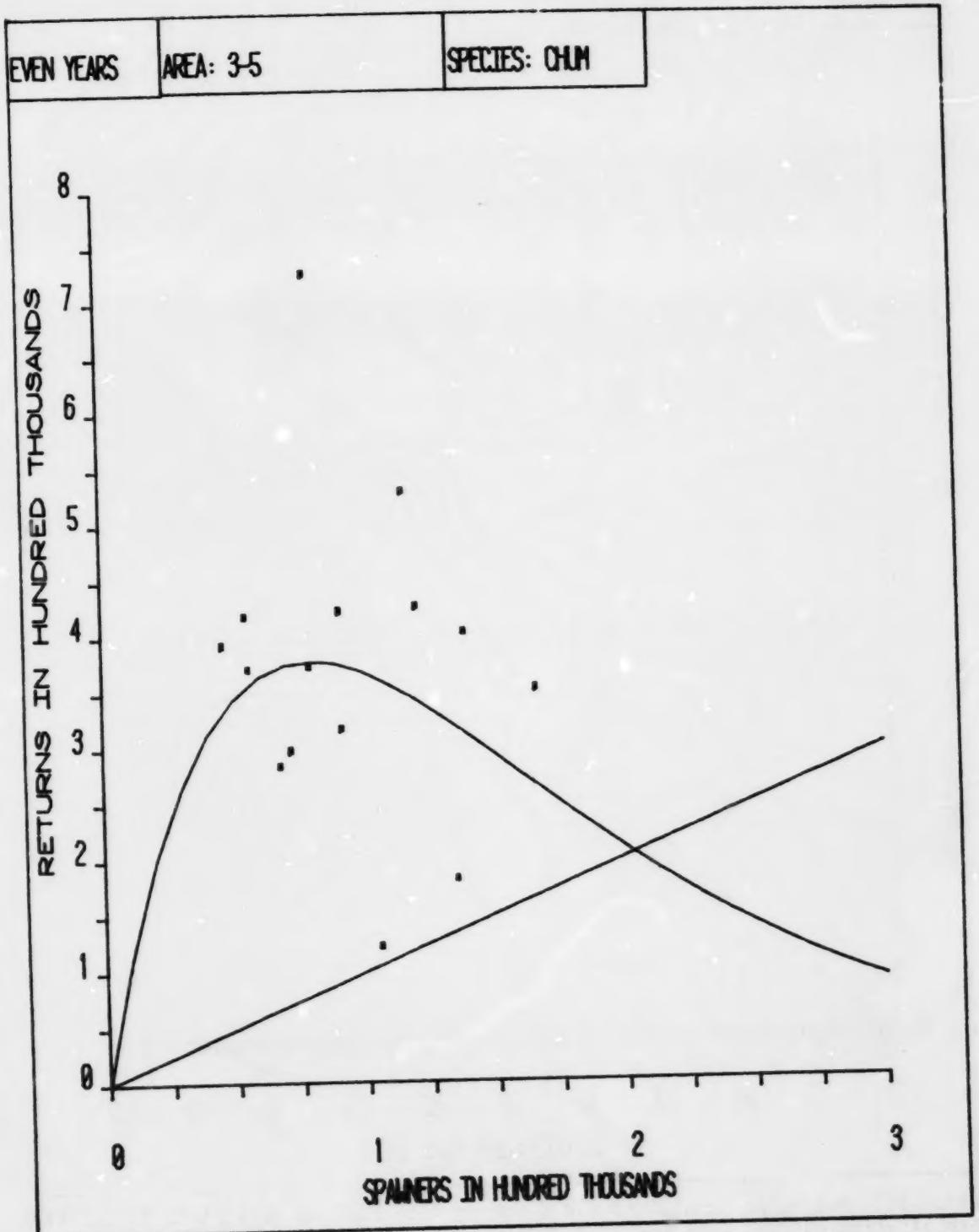

Fig. 29. Stock and recruitment curves for even broodyears 1948-1976 of North Coast chum salmon.

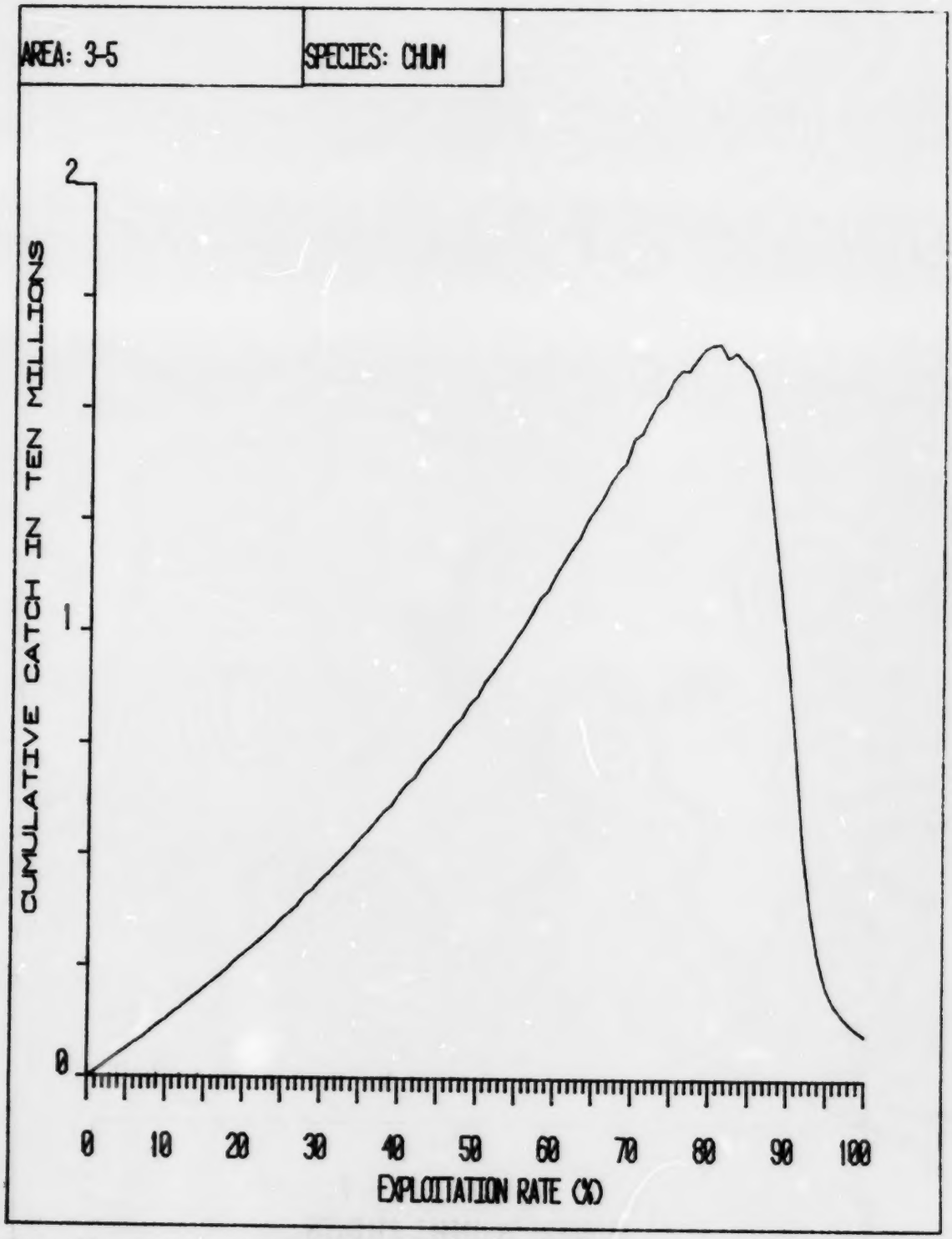

Fig. 30. Projected cumulative yield during 1960-2020 by harvesting at constant exploitation rate in each year for North Coast chum salmon.

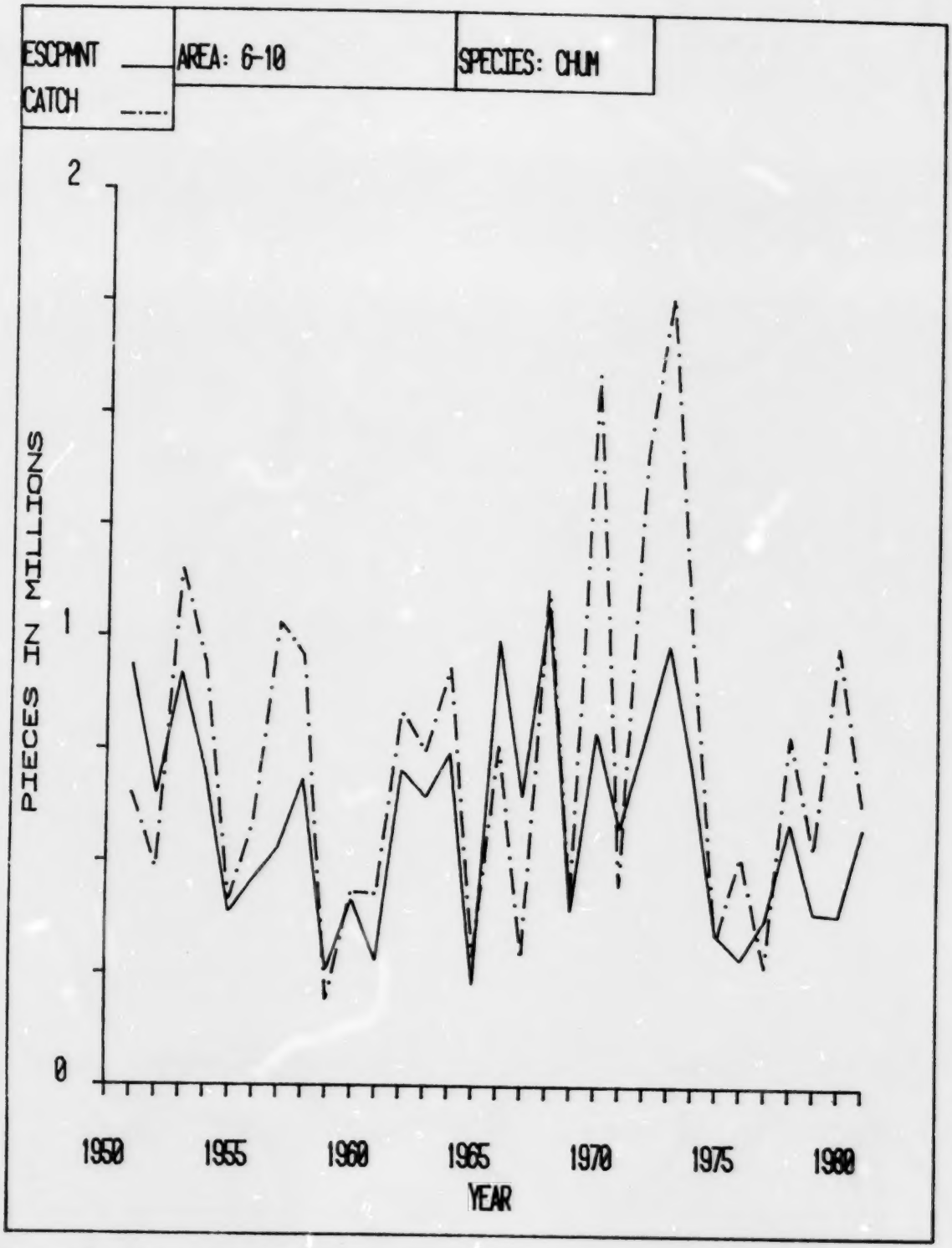

Fig. 31. Catch and escapement of Central Coast chum salmon.

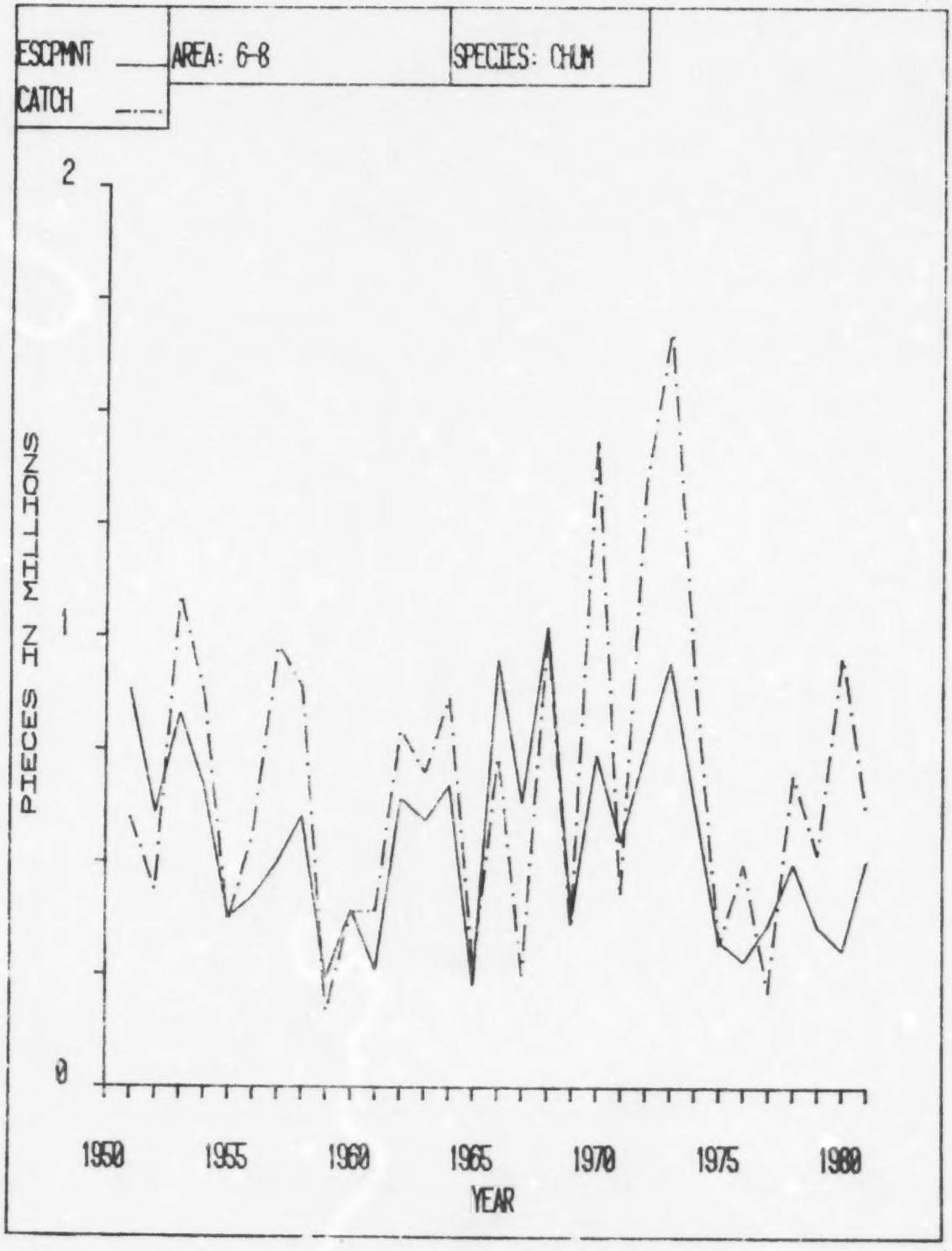

Fig. 32. Catch and escapement of chum salmon in Statistical Areas 6-8.

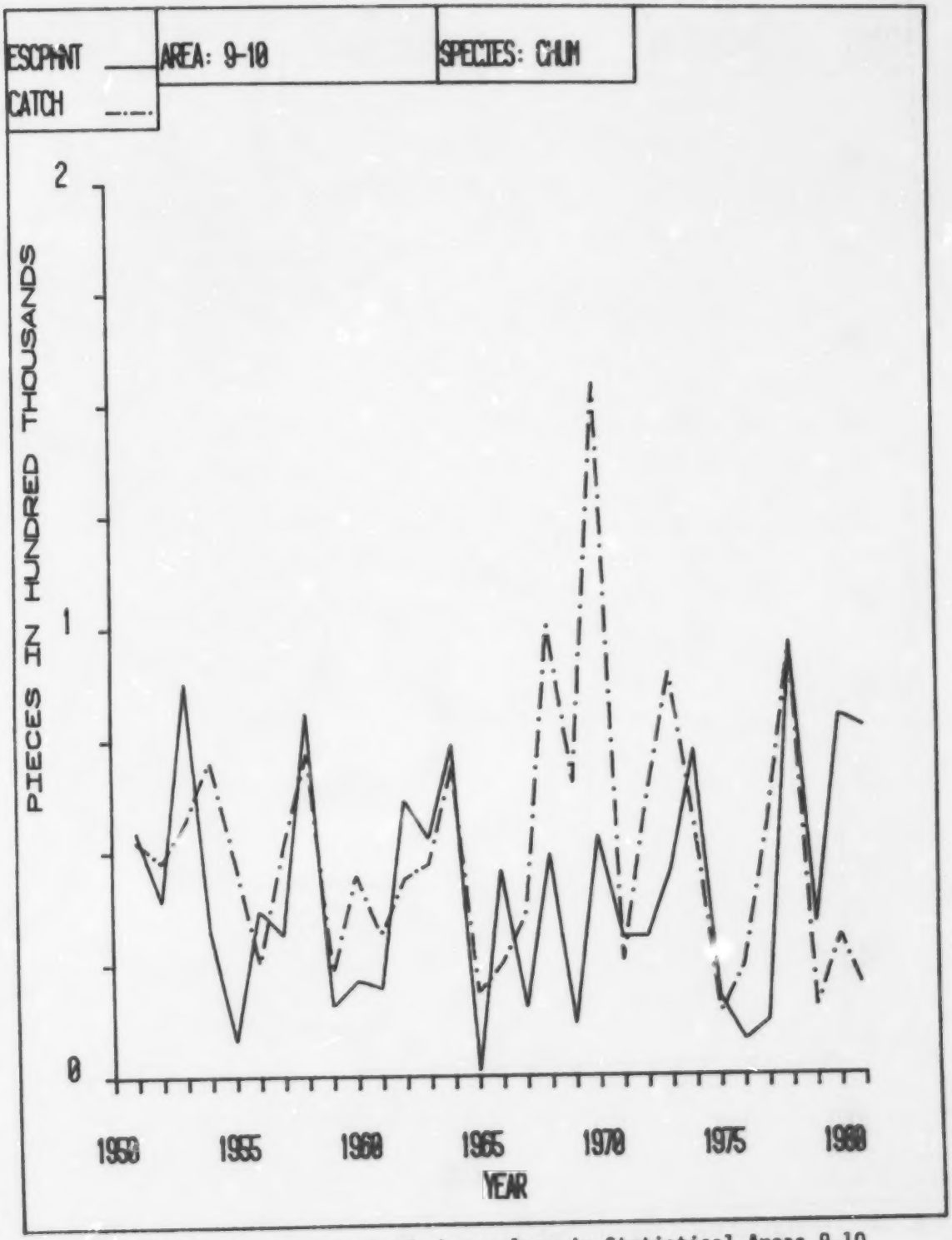

Fig. 33. Catch and escapement of chum salmon in Statistical Areas 9-10.

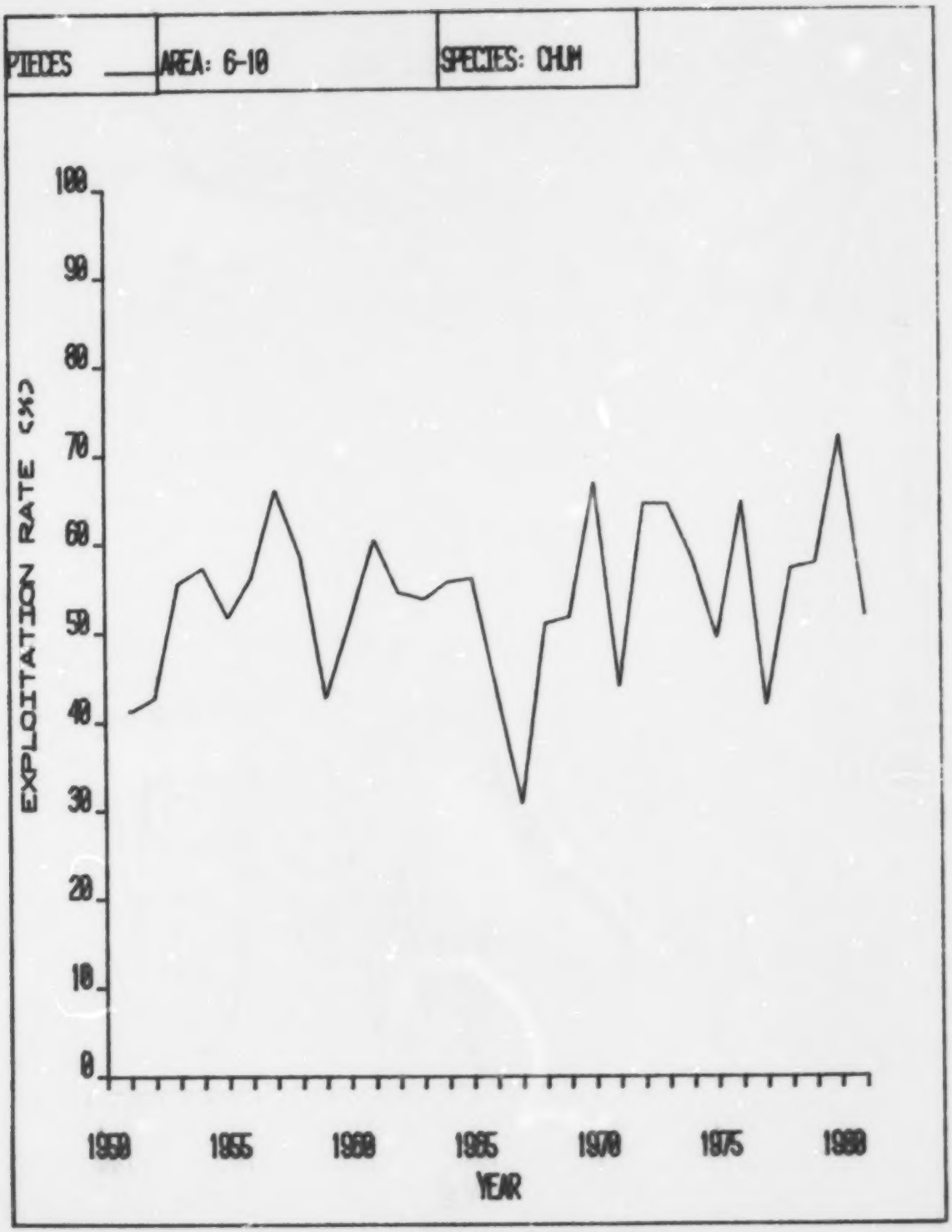

Fig. 34. Exploitation rate of Central Coast chum salmon.

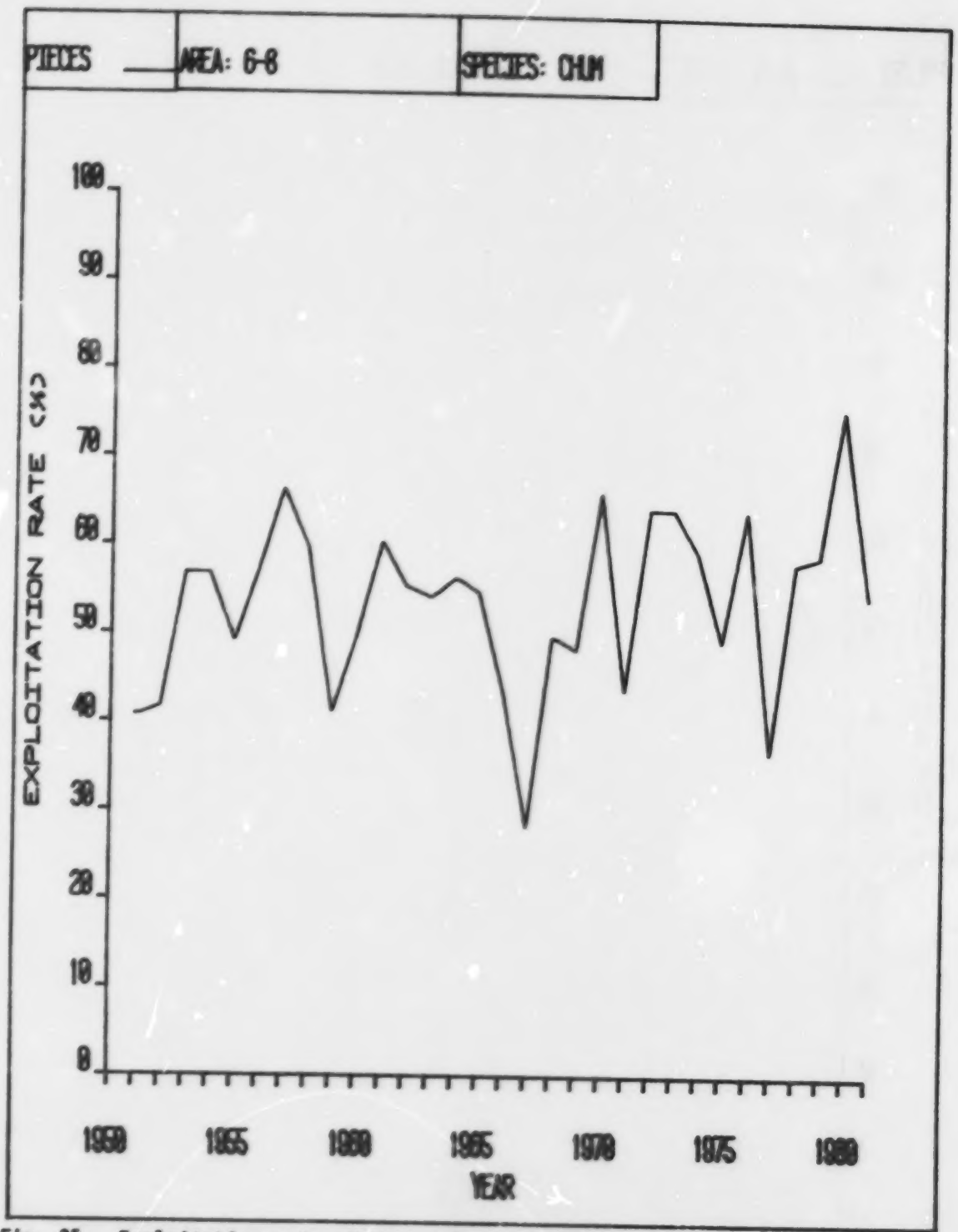

Fig. 35. Exploitation rate of chum salmon in Statistical Areas 6-8.

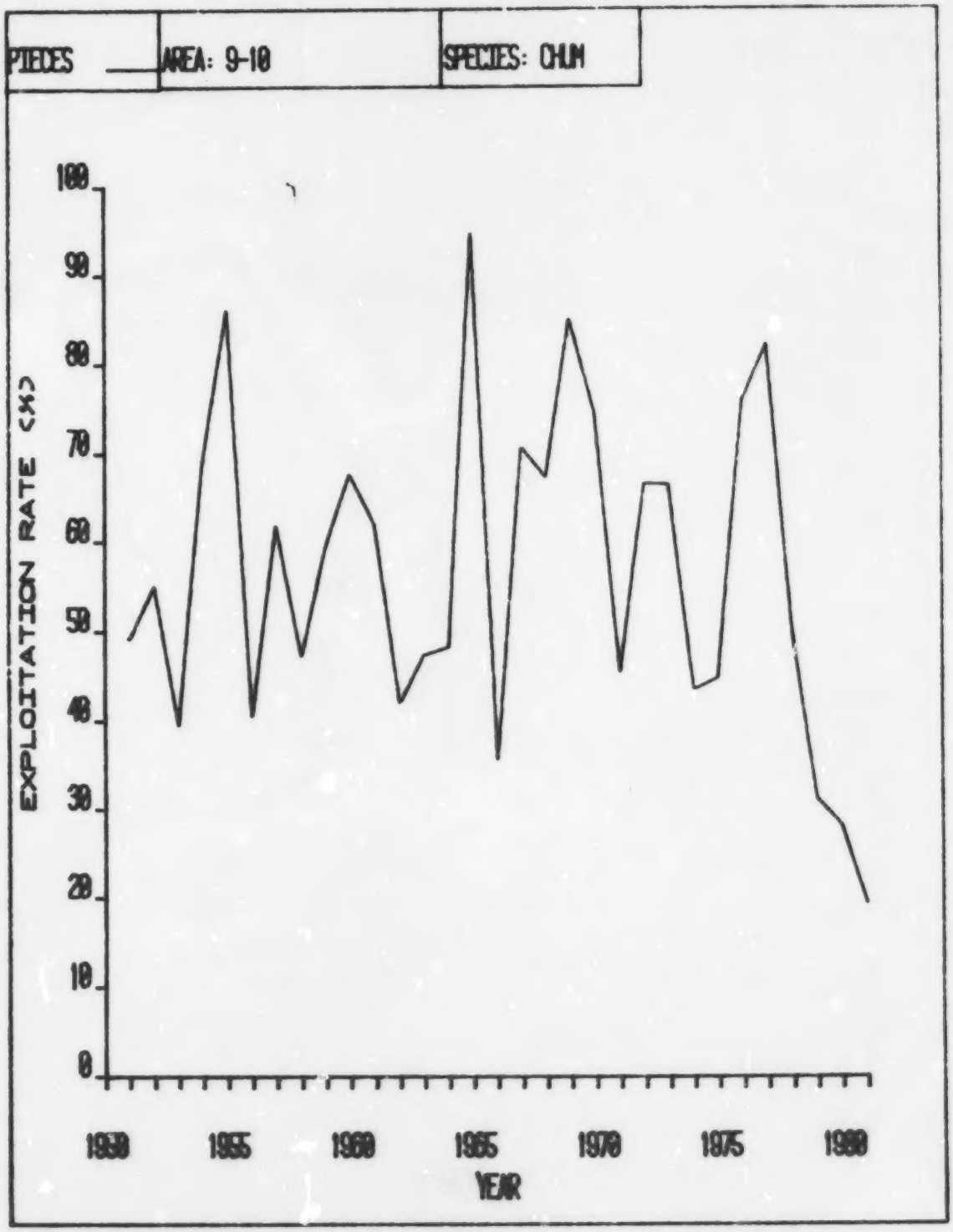

Fig. 36. Exploitation rate of chum salmon in Statistical Areas 9-10.

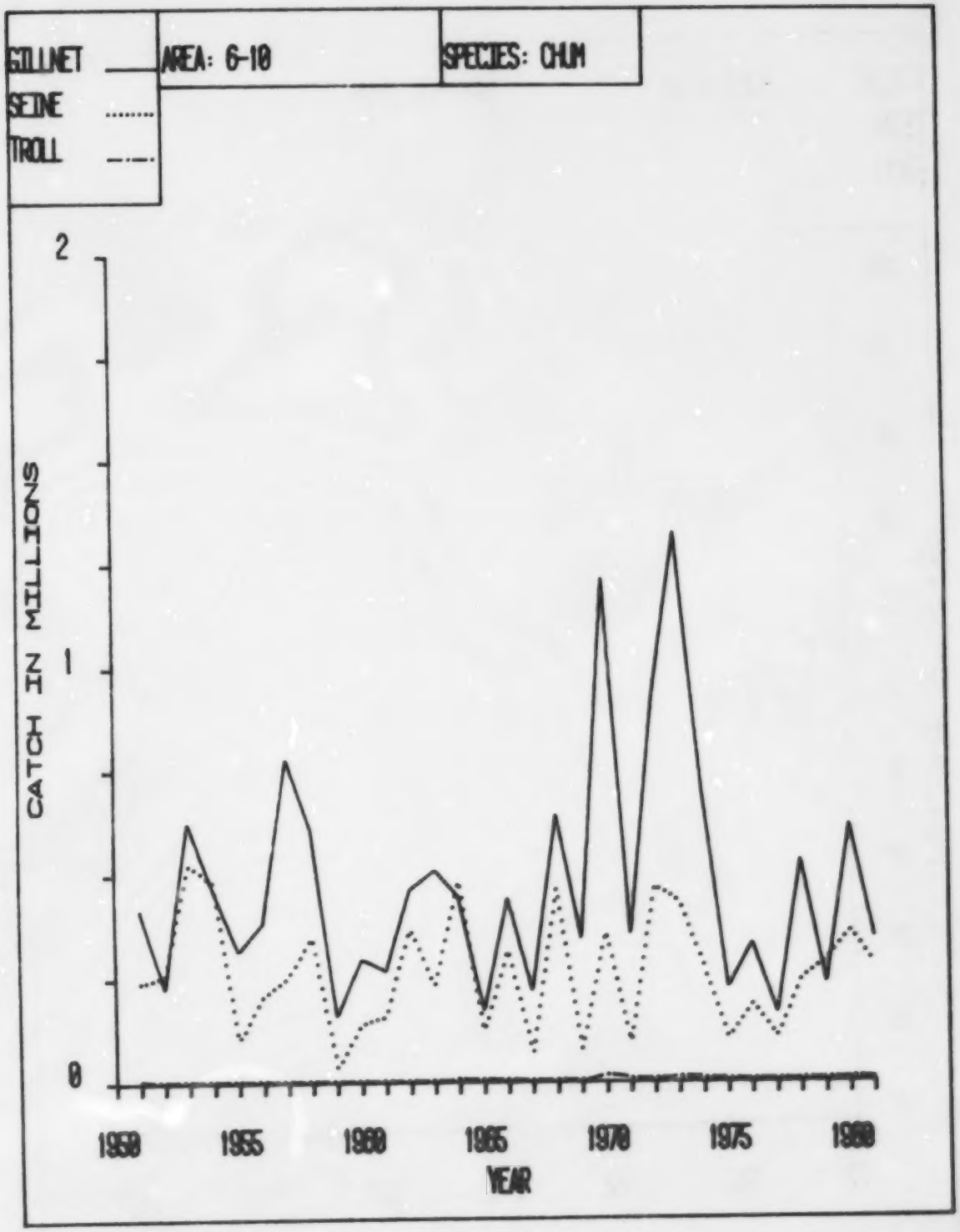

Fig. 37. Catch by gear of Central Coast chum salmon.

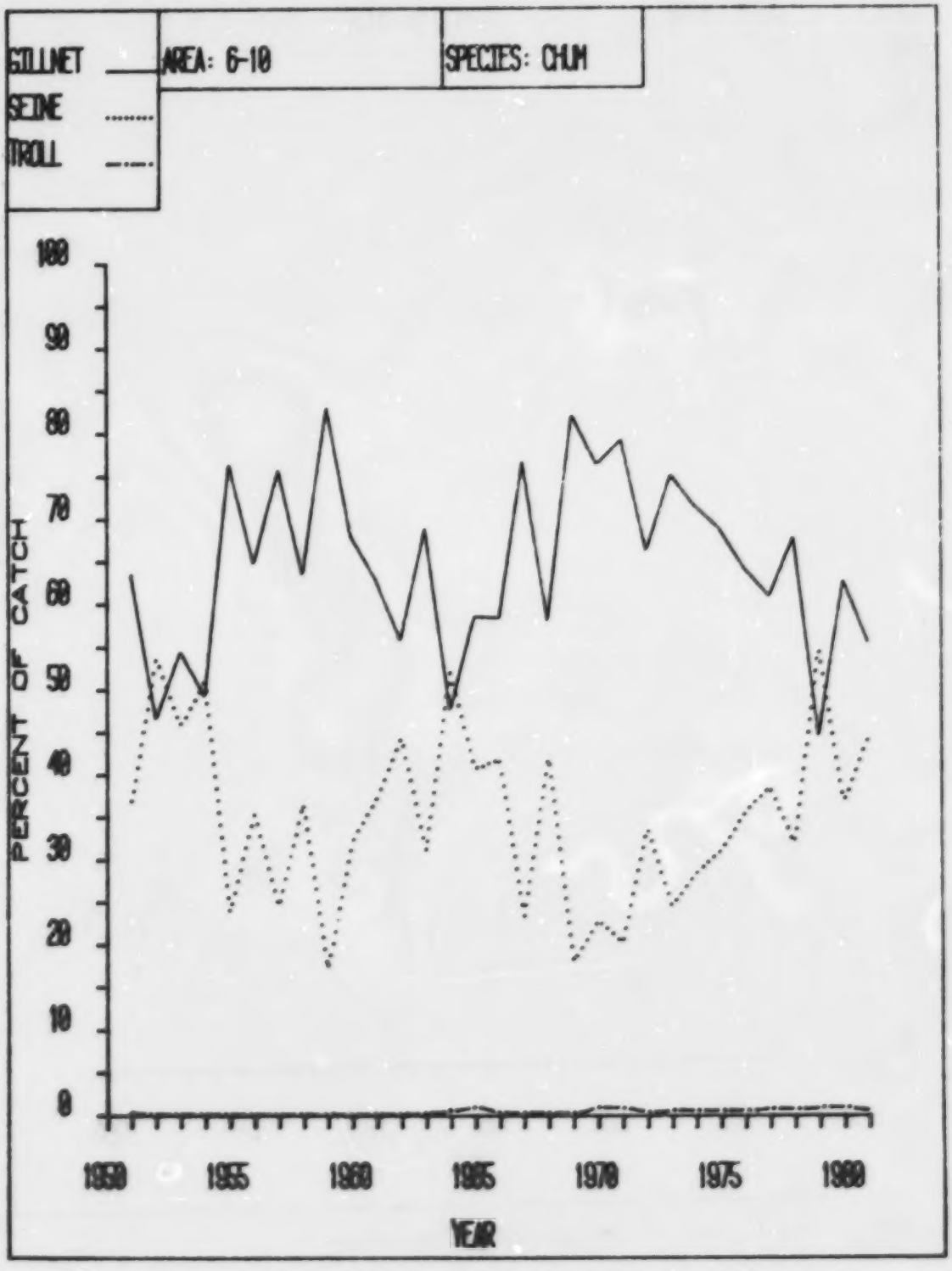

Fig. 38. Percent of total catch by gear of Central Coast chum salmon.

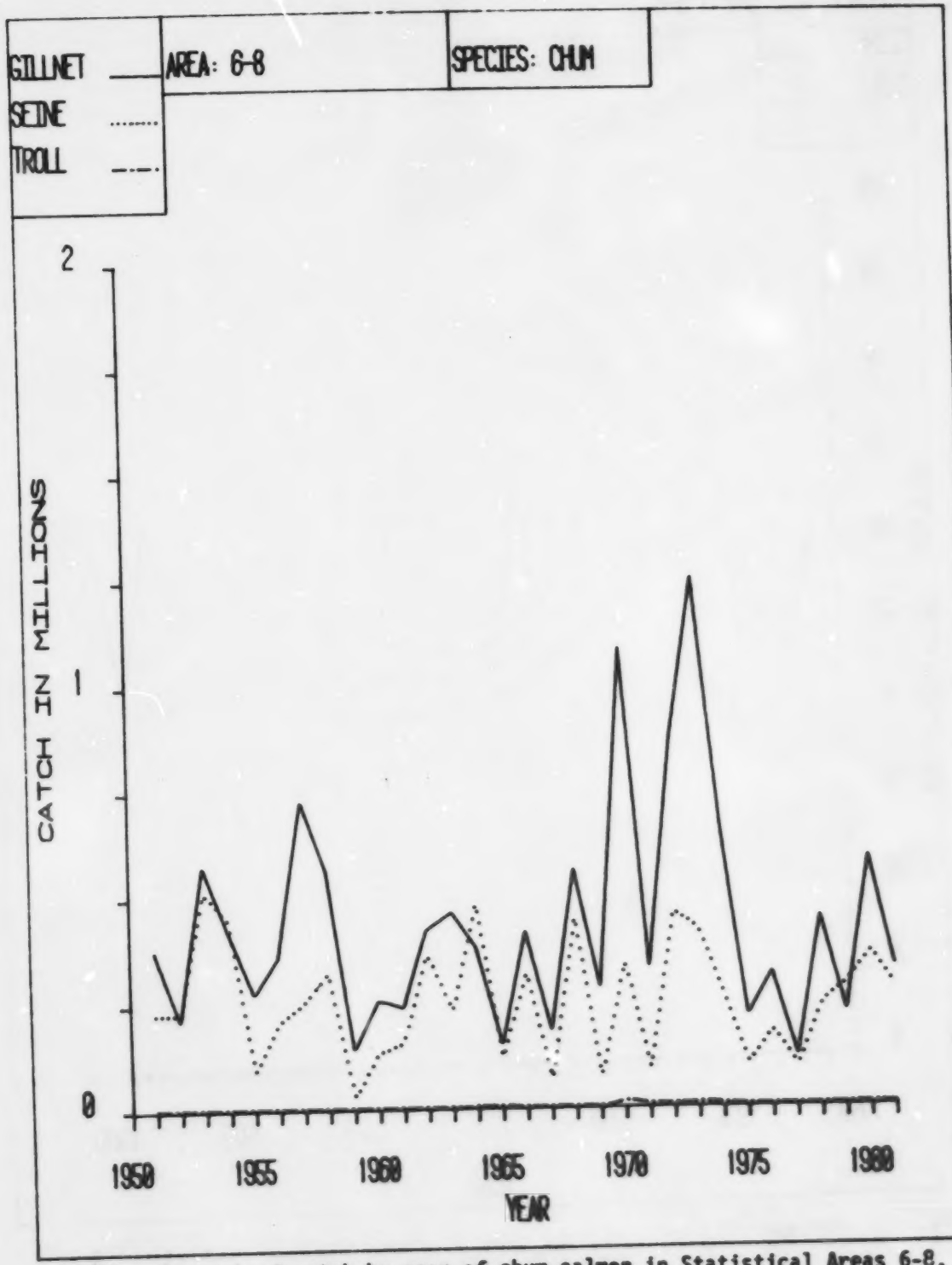

Fig. 39. Percent of catch by gear of chum salmon in Statistical Areas 6-8.

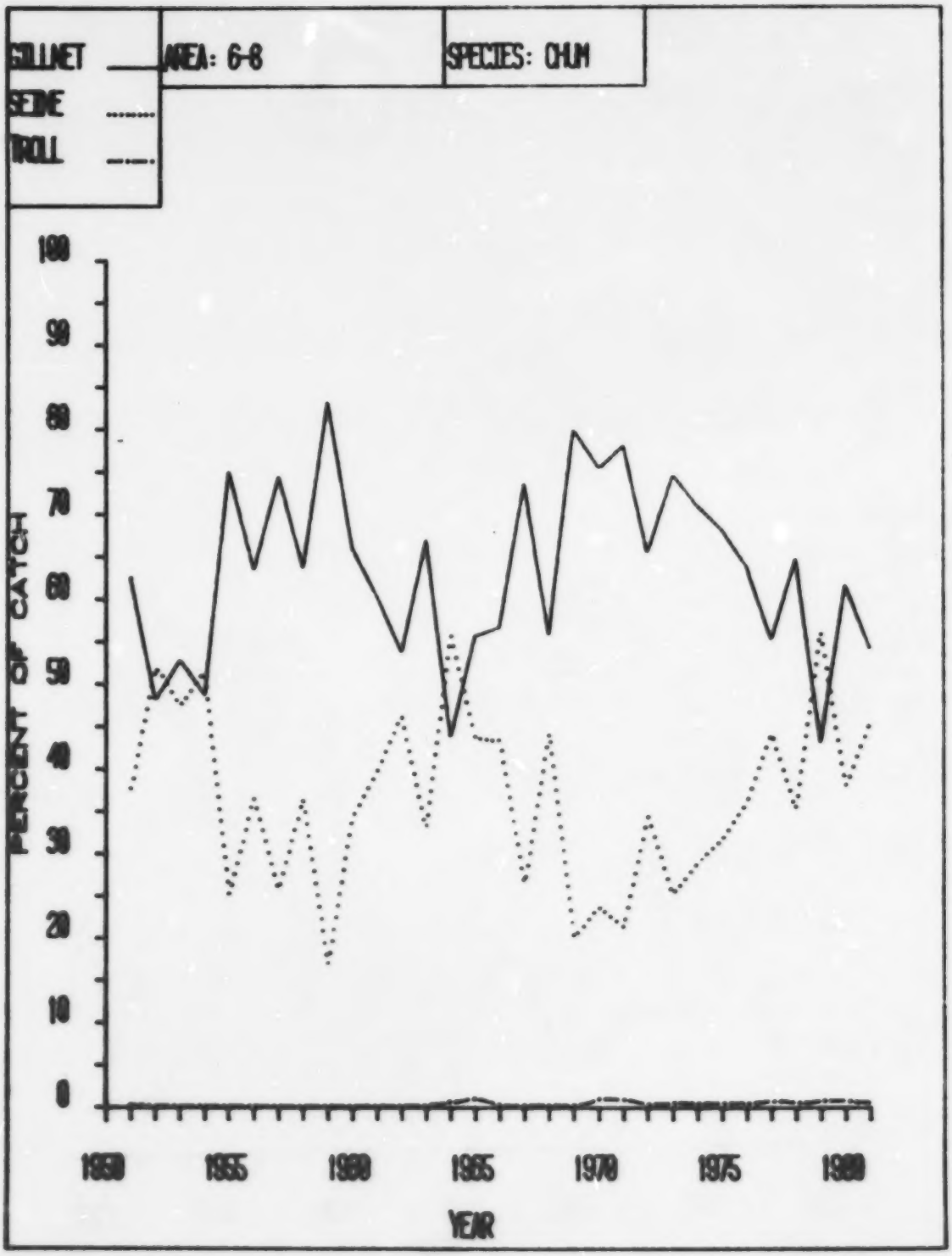

Fig. 40. Percent of total catch by gear of chum salmon in Statistical Areas 6-8.

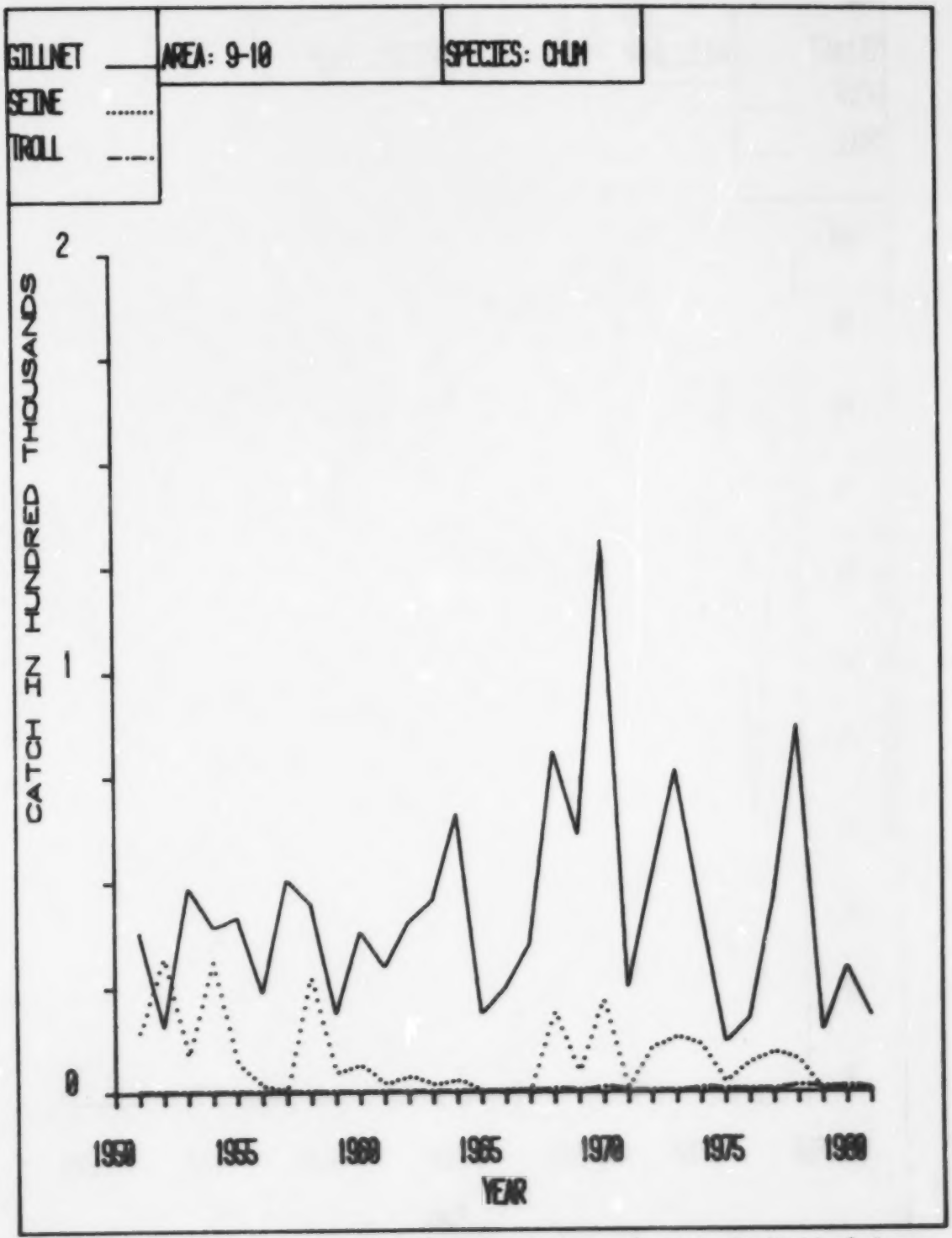

Fig. 41. Percent of total catch by gear of chum salmon in Statistical Areas 9-10.

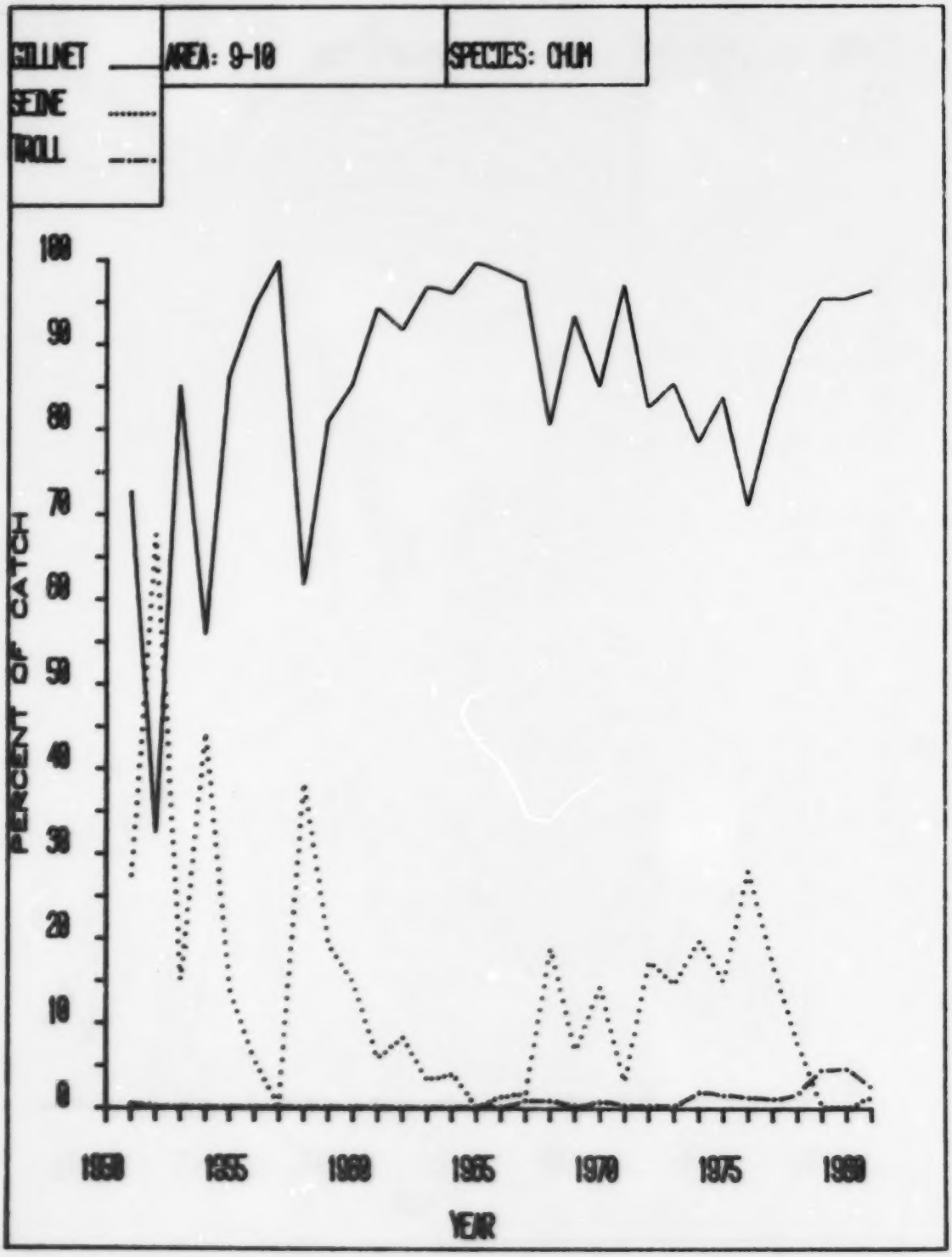

Fig. 42. Percent of total catch by gear of chum salmon in Statistical Areas 9-10.

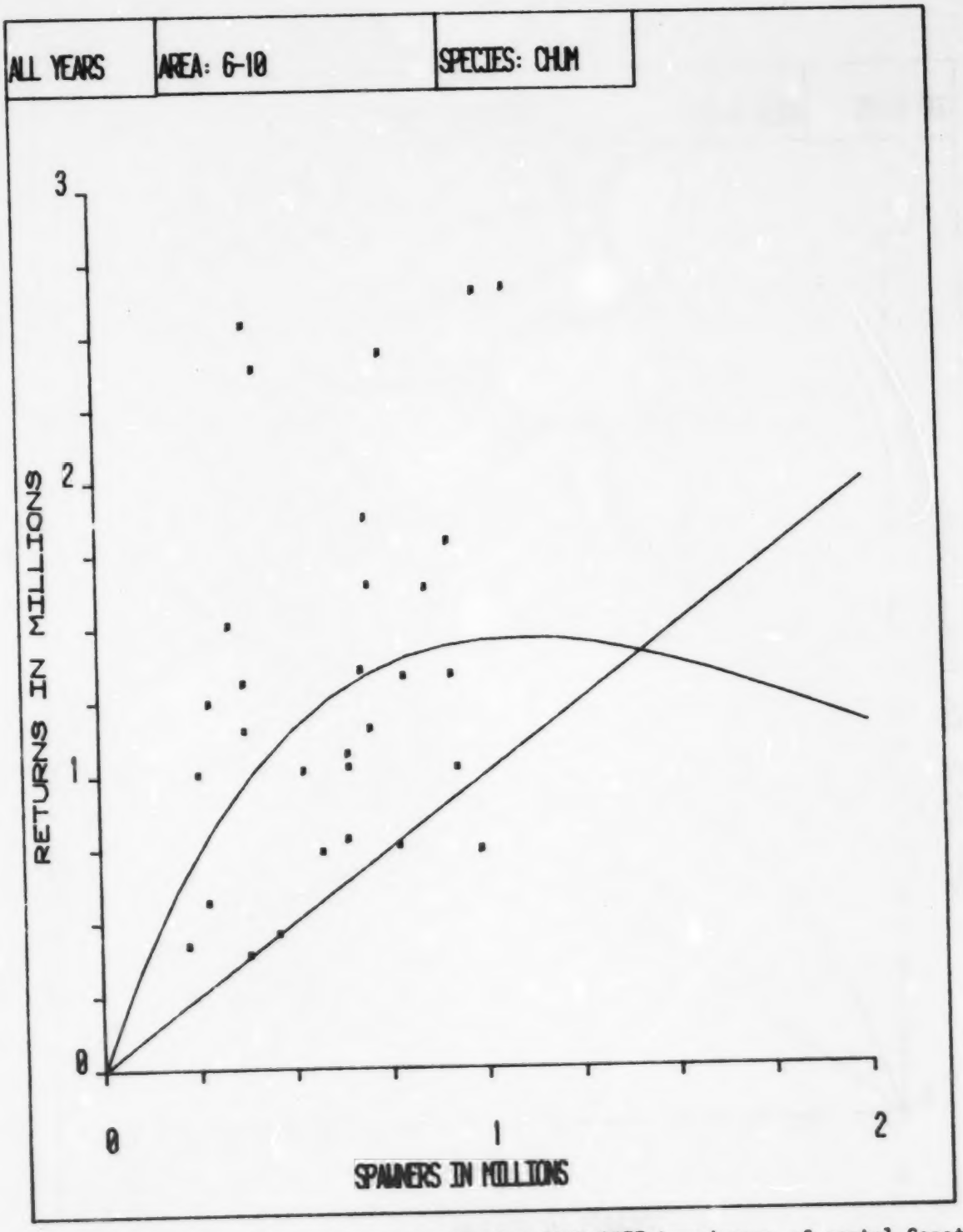

Fig. 43. Stock and recruitment curves for 1948-1977 broodyears of centrl Coast chum salmon.

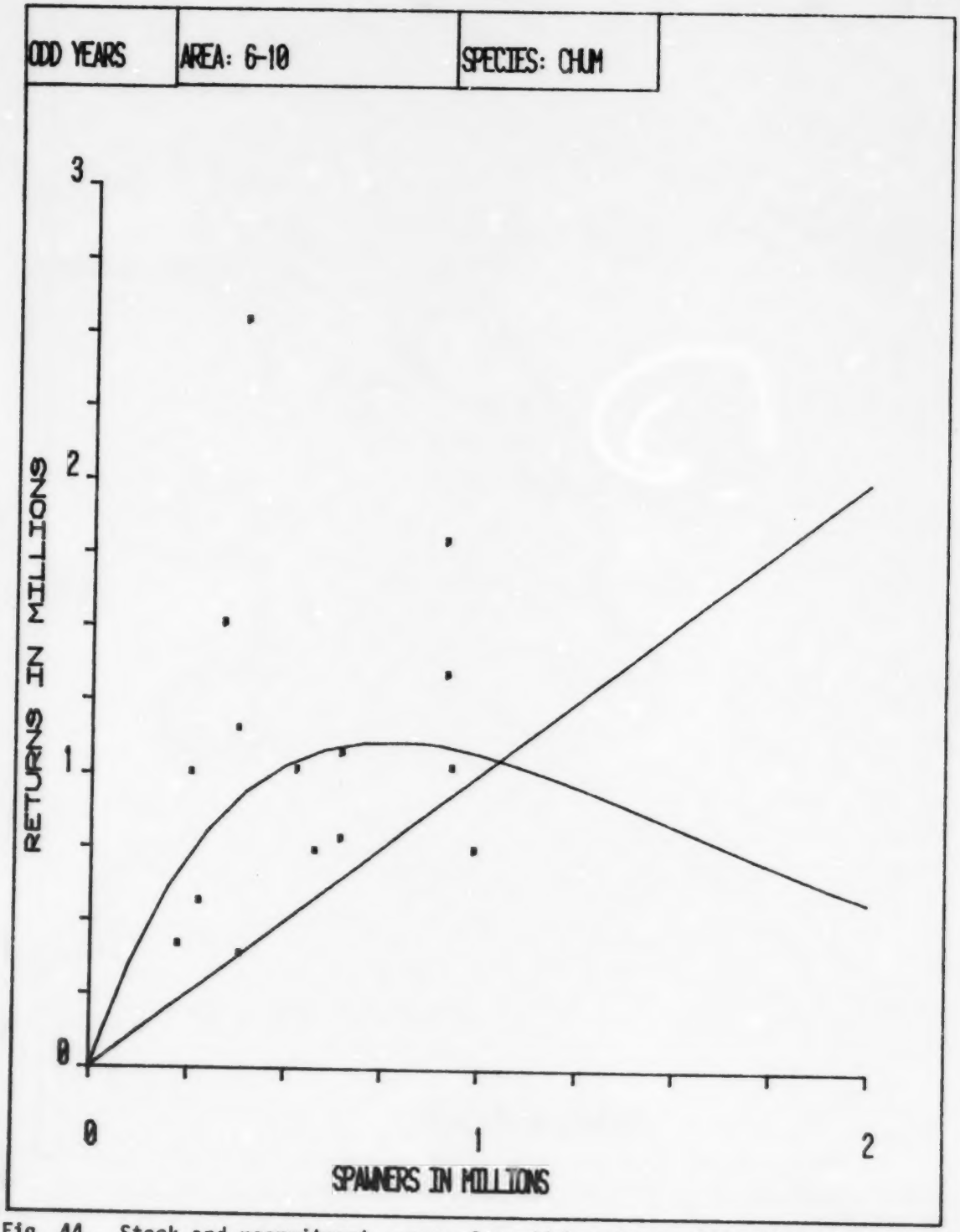

Fig. 44. Stock and recruitment curves for odd broodyears 1949-1977 of Central Coast chum salmon.

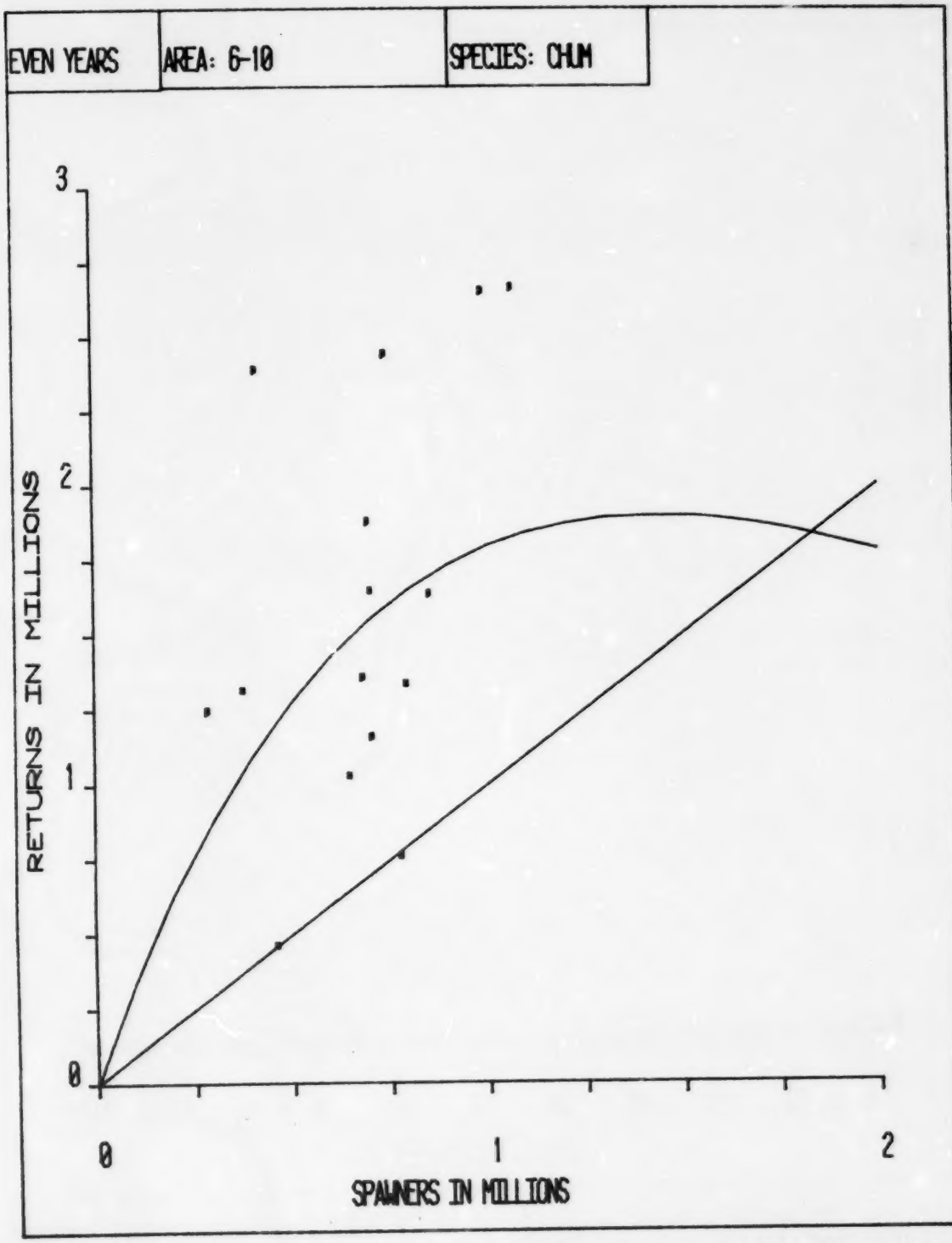

Fig. 45. Stock and recruitment curves for even broodyears 1948-1976 of Central Coast chum salmon.

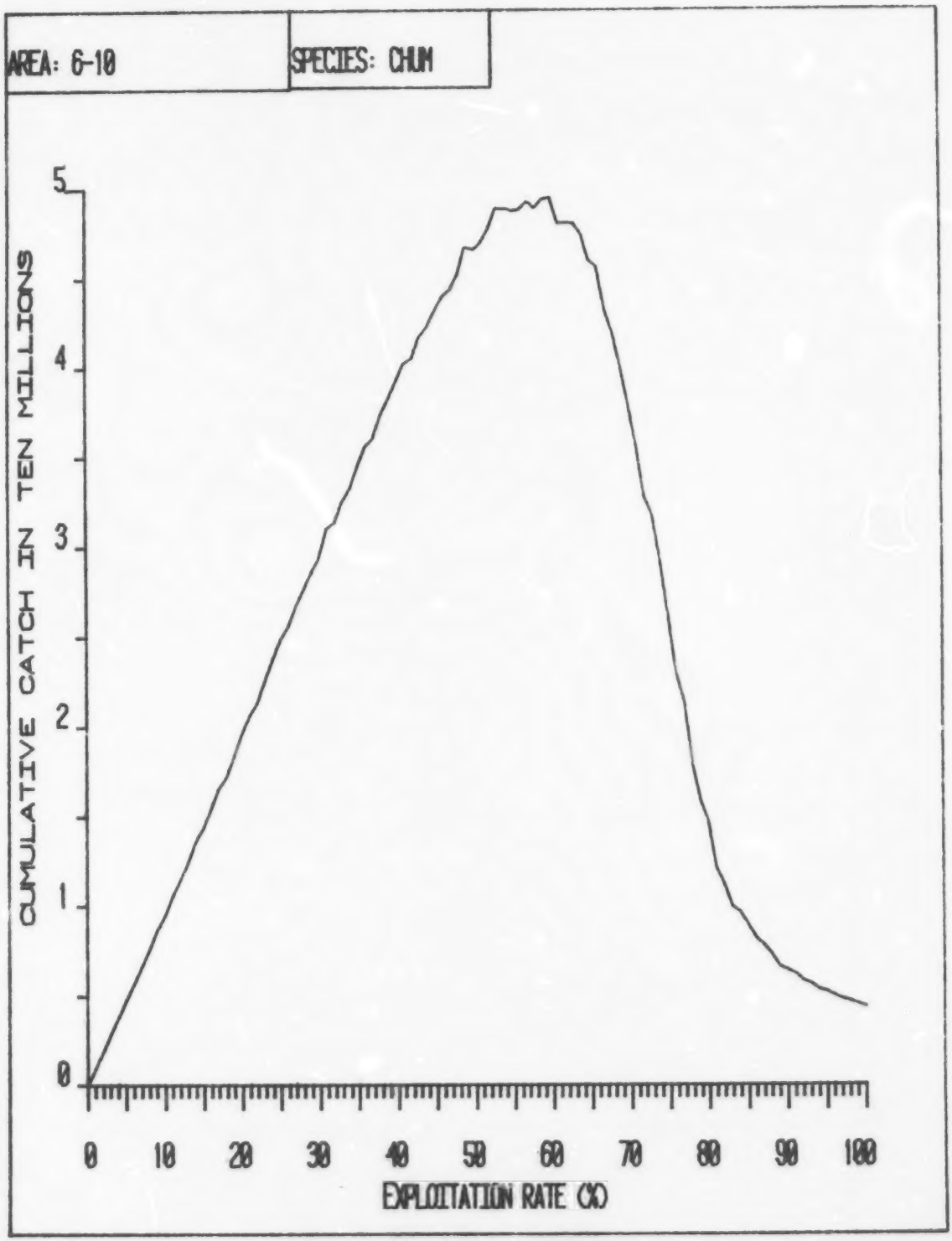

Fig. 46. Projected cumulative yield during 1960-2020 by harvesting at constant exploitation rate in each year for Central Coast chum salmon.

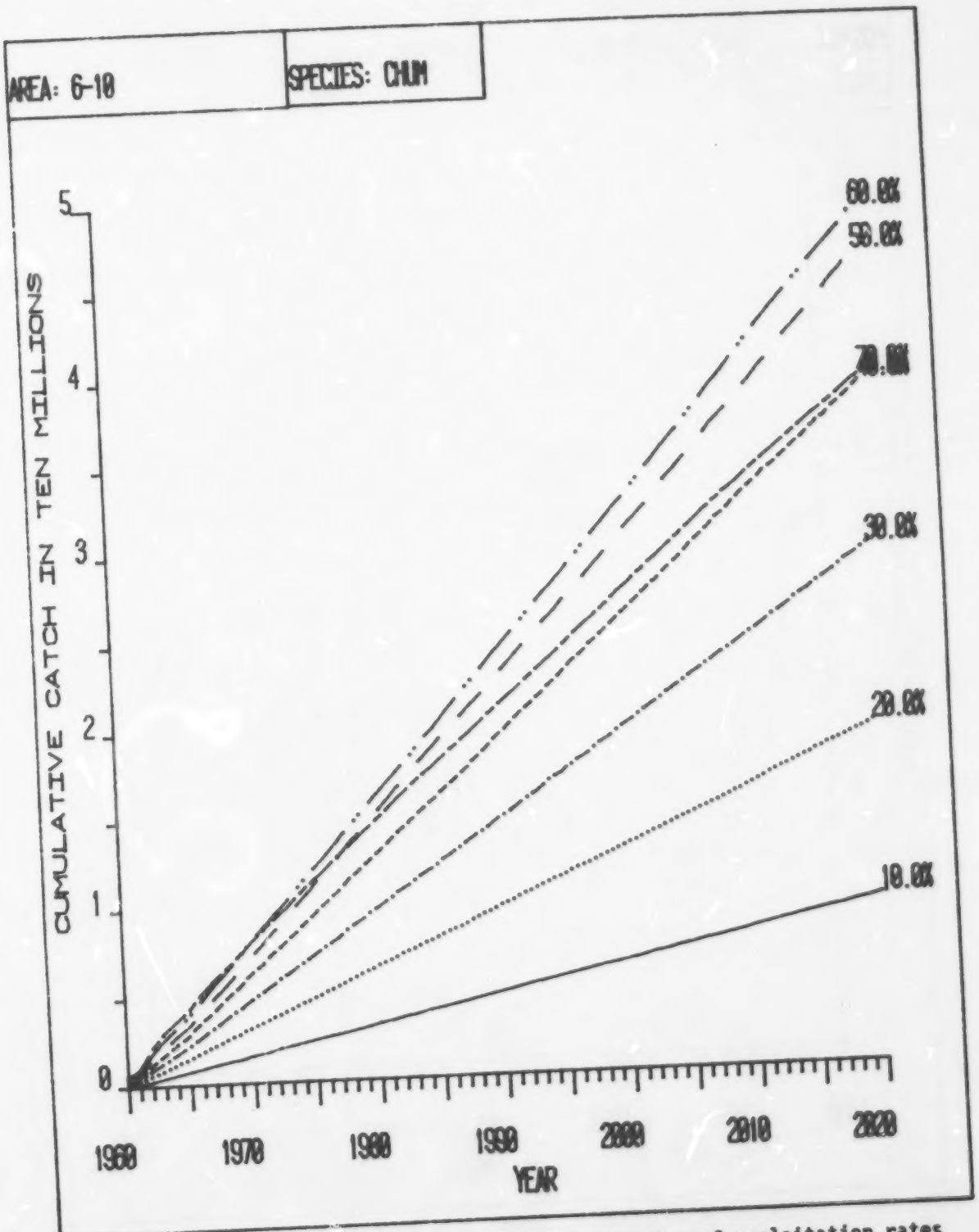

Fig. 47. Summary of yields under a 60 year projection of exploitation rates of 10-70% for Central Coast chum salmon.

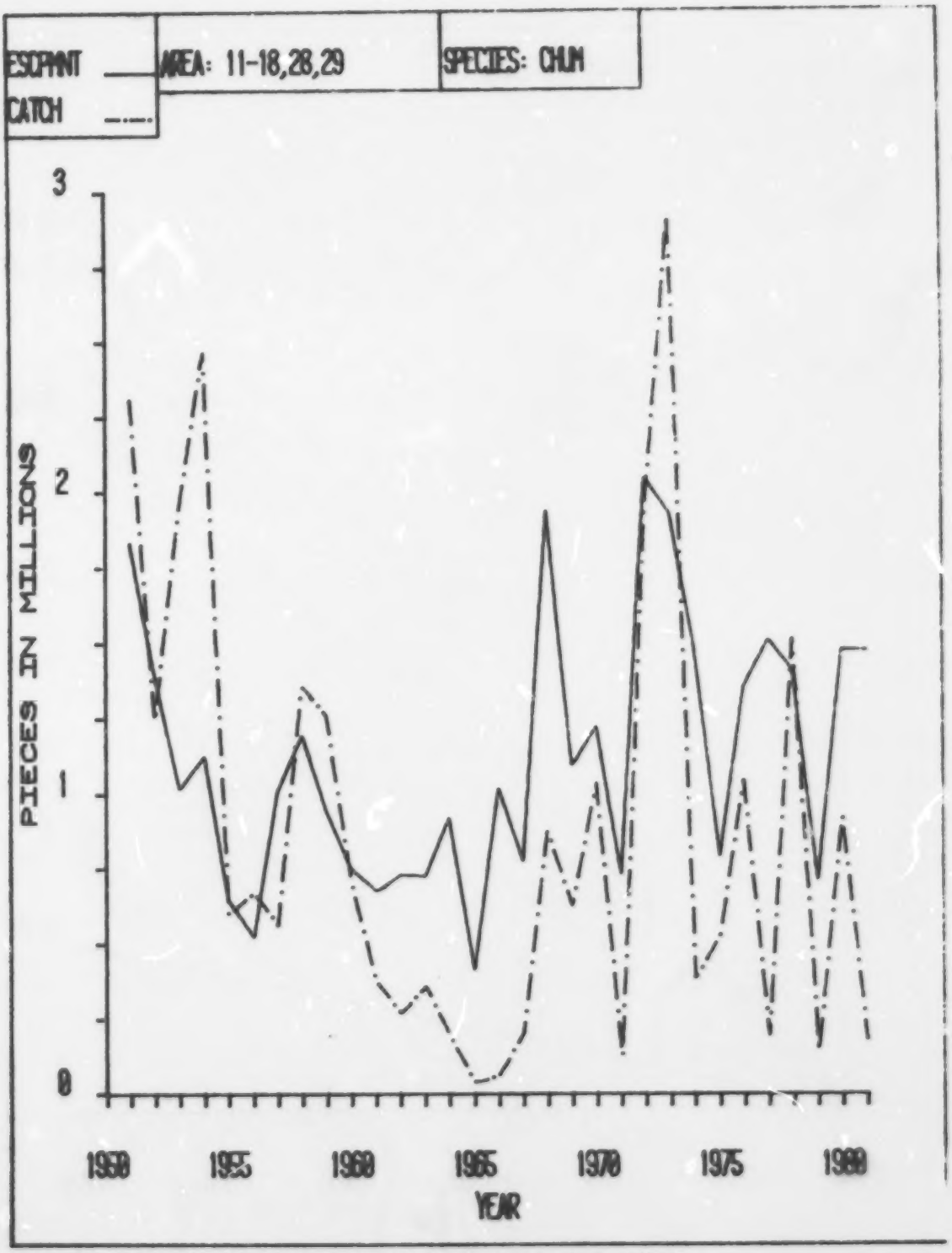

Fig. 48. Catch and escapement of Study Area chum salmon.

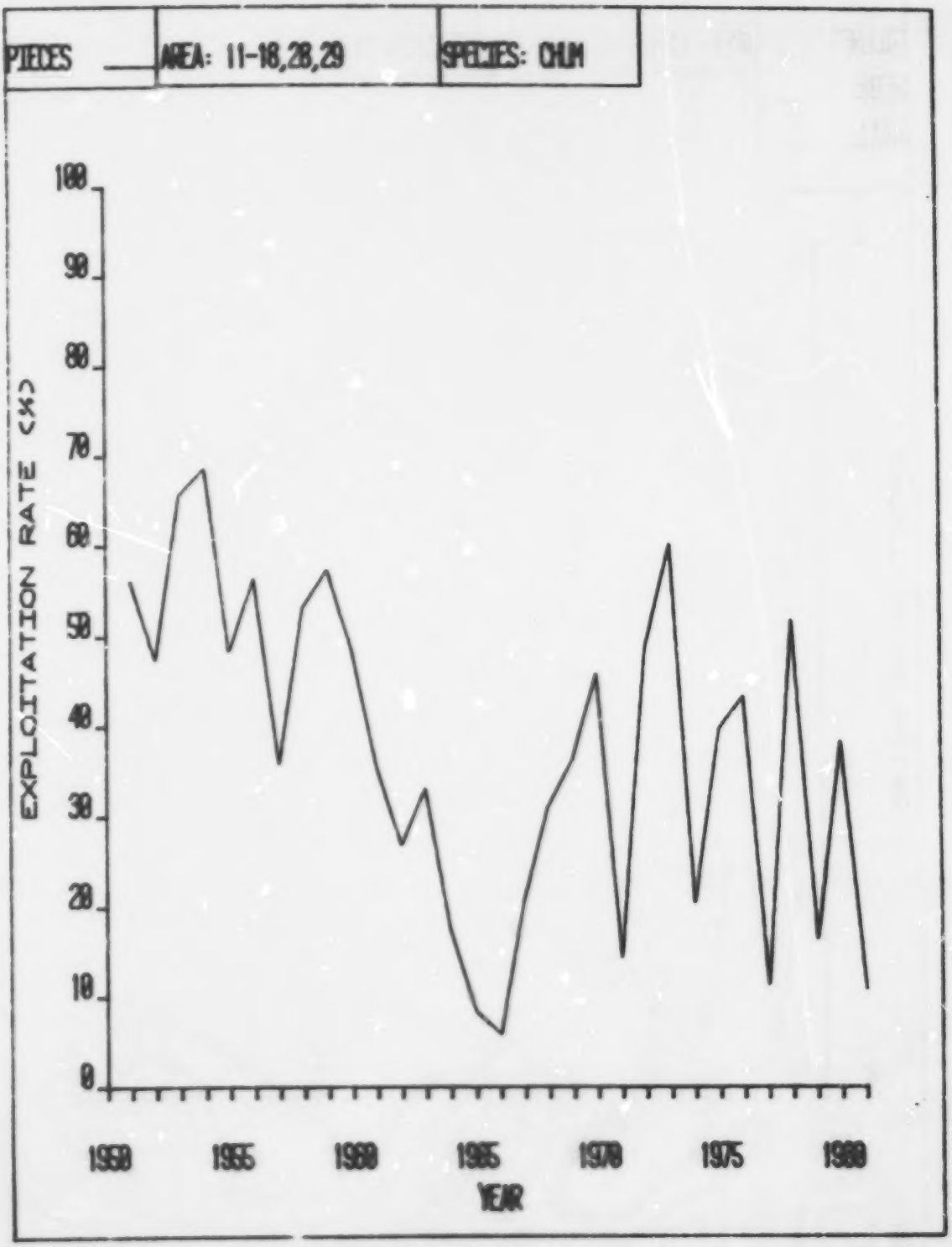

Fig. 49. Exploitation rate of Study Area chum salmon.

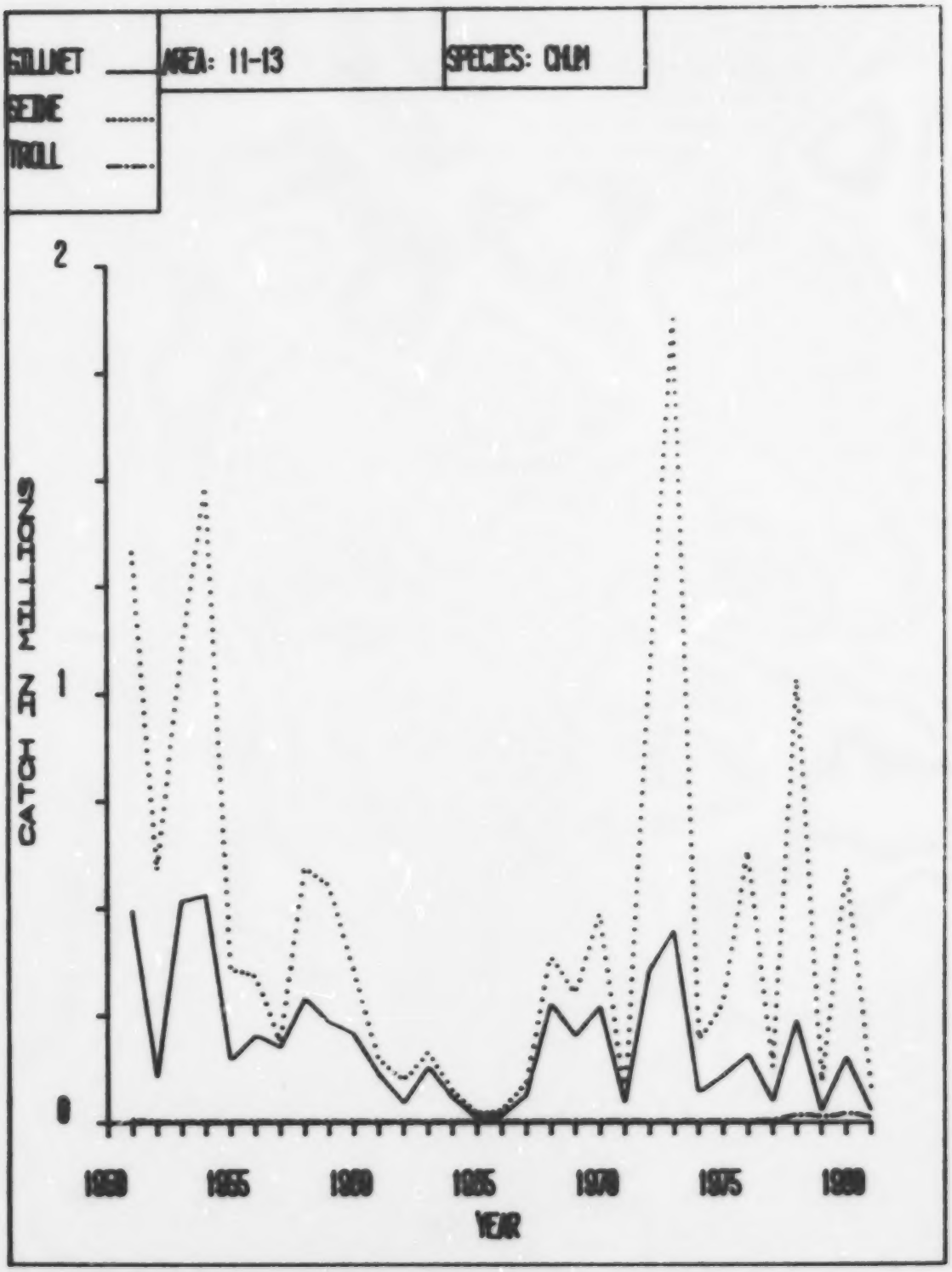

Fig. 50. Catch by gear of chum salmon in Johnstone Strait.

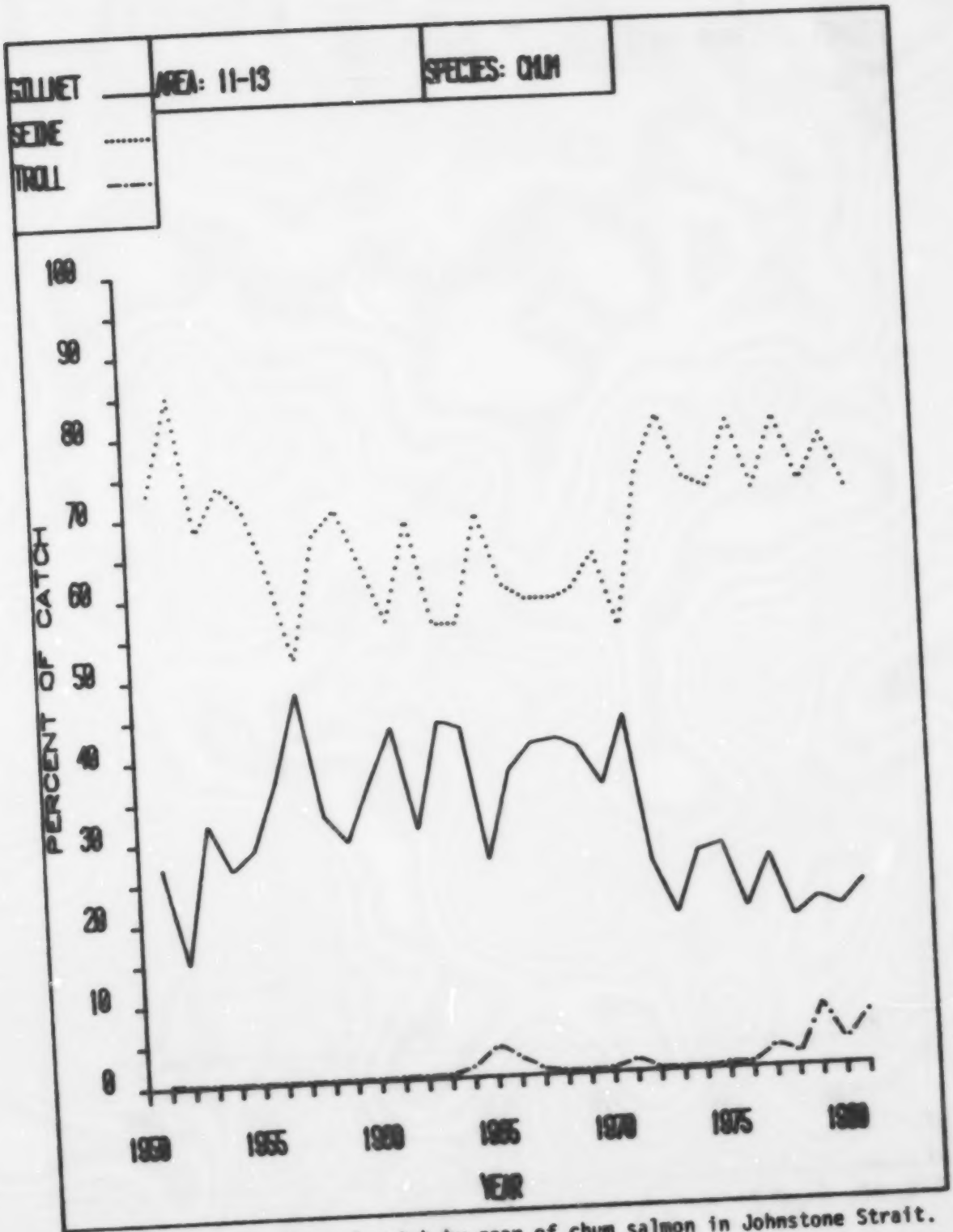

Fig. 51. Percent of total catch by gear of chum salmon in Johnstone Strait.

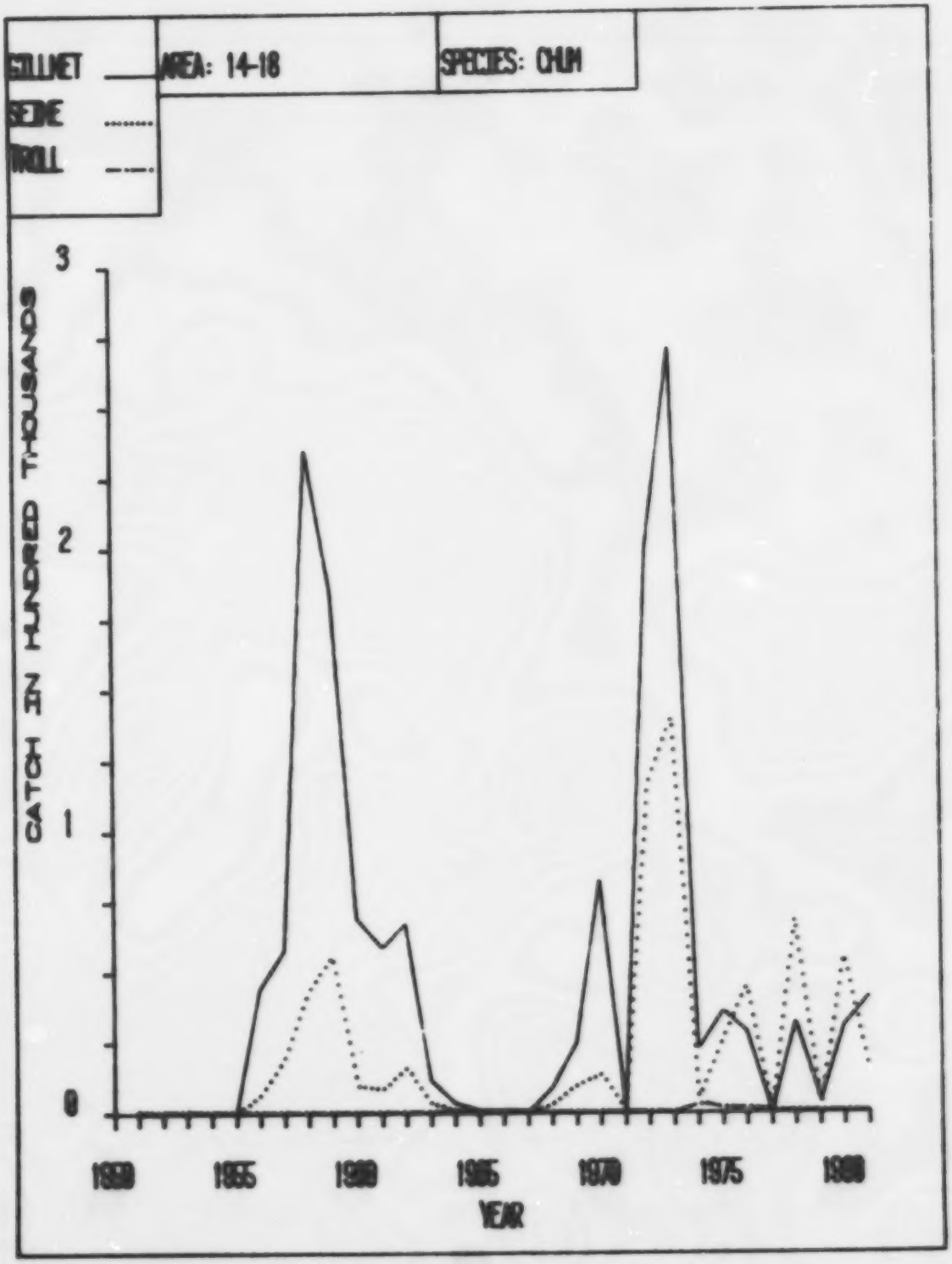

Fig. 52. Catch by gear of chum salmon in Georgia Strait.

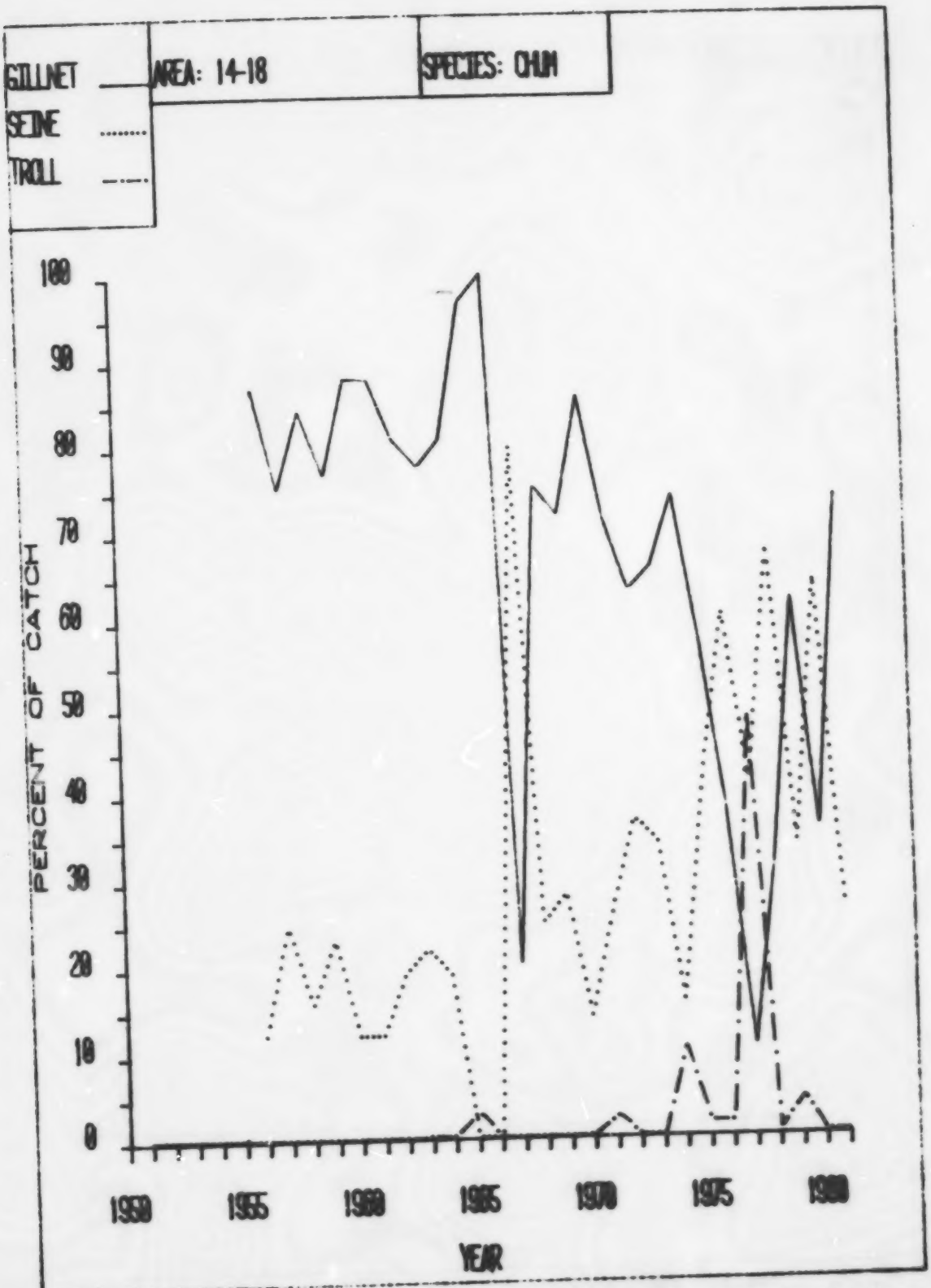

Fig. 53. Percent of total catch by gear of chum salmon in Georgia Strait.

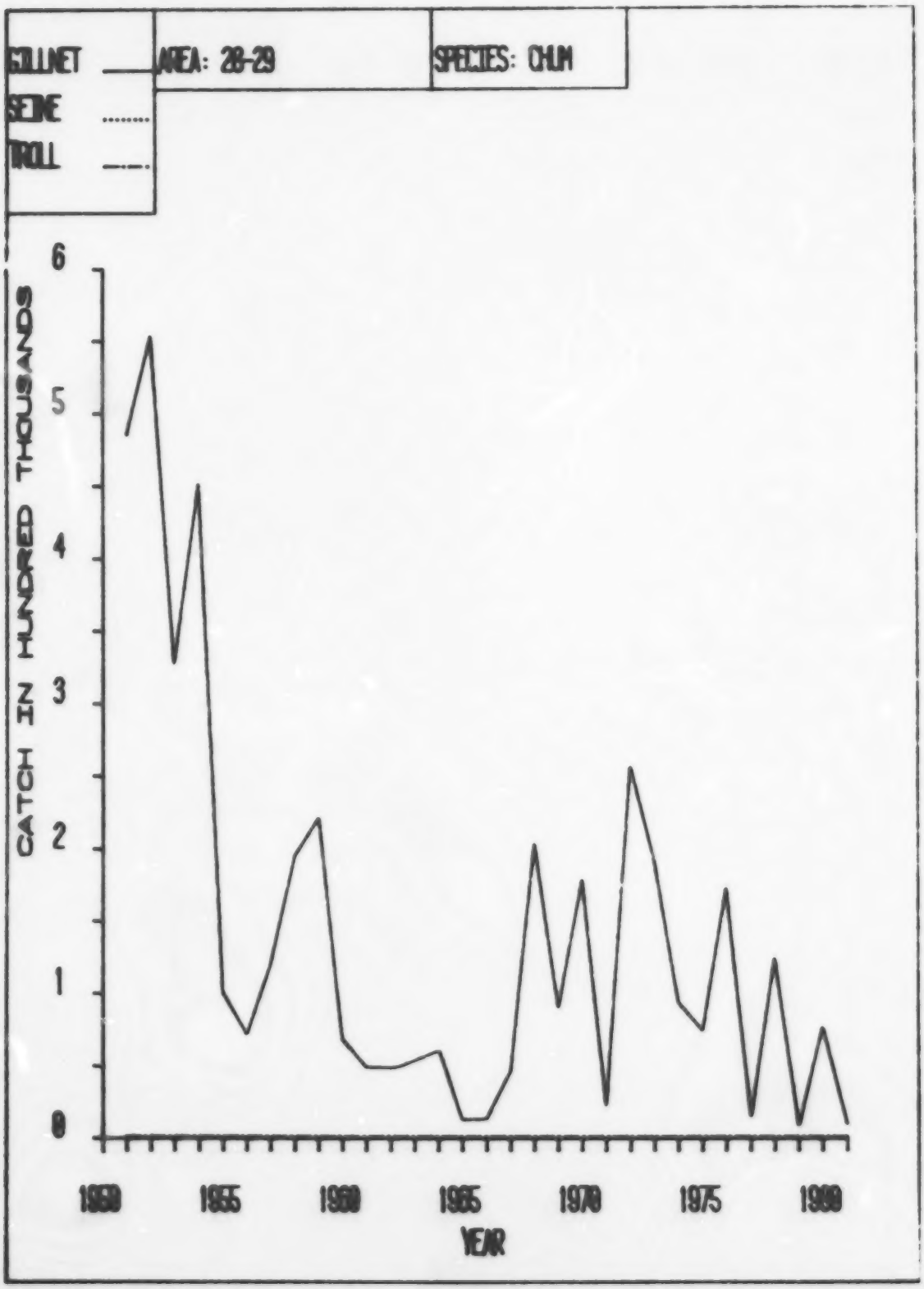

Fig. 54. Catch of chum salmon by gillnetters in Statistical Areas 28-29.

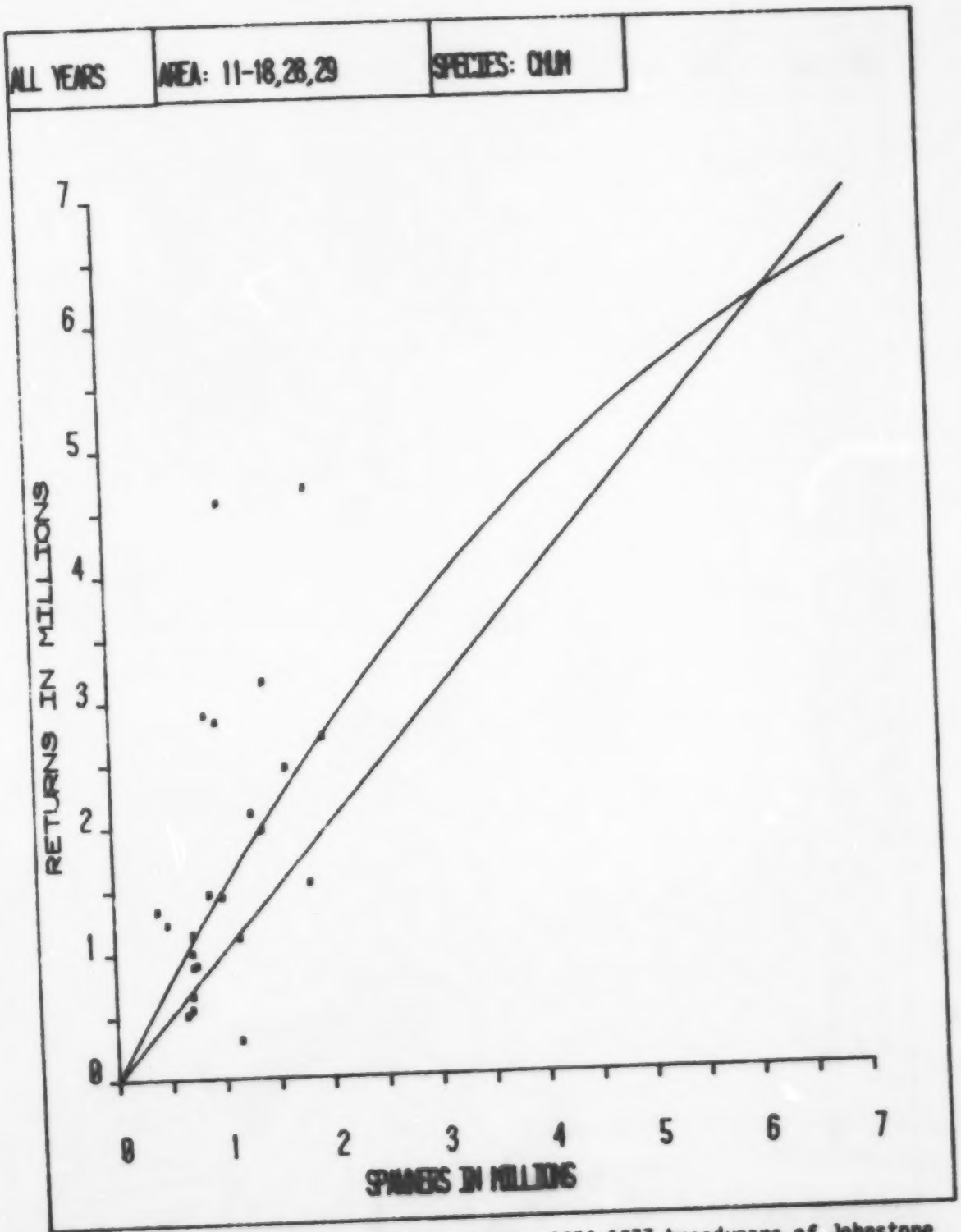

Fig. 55. Stock and recruitment curves for 1956-1977 broodyears of Johnstone Strait, Georgia Strait, and Fraser River chum salmon.

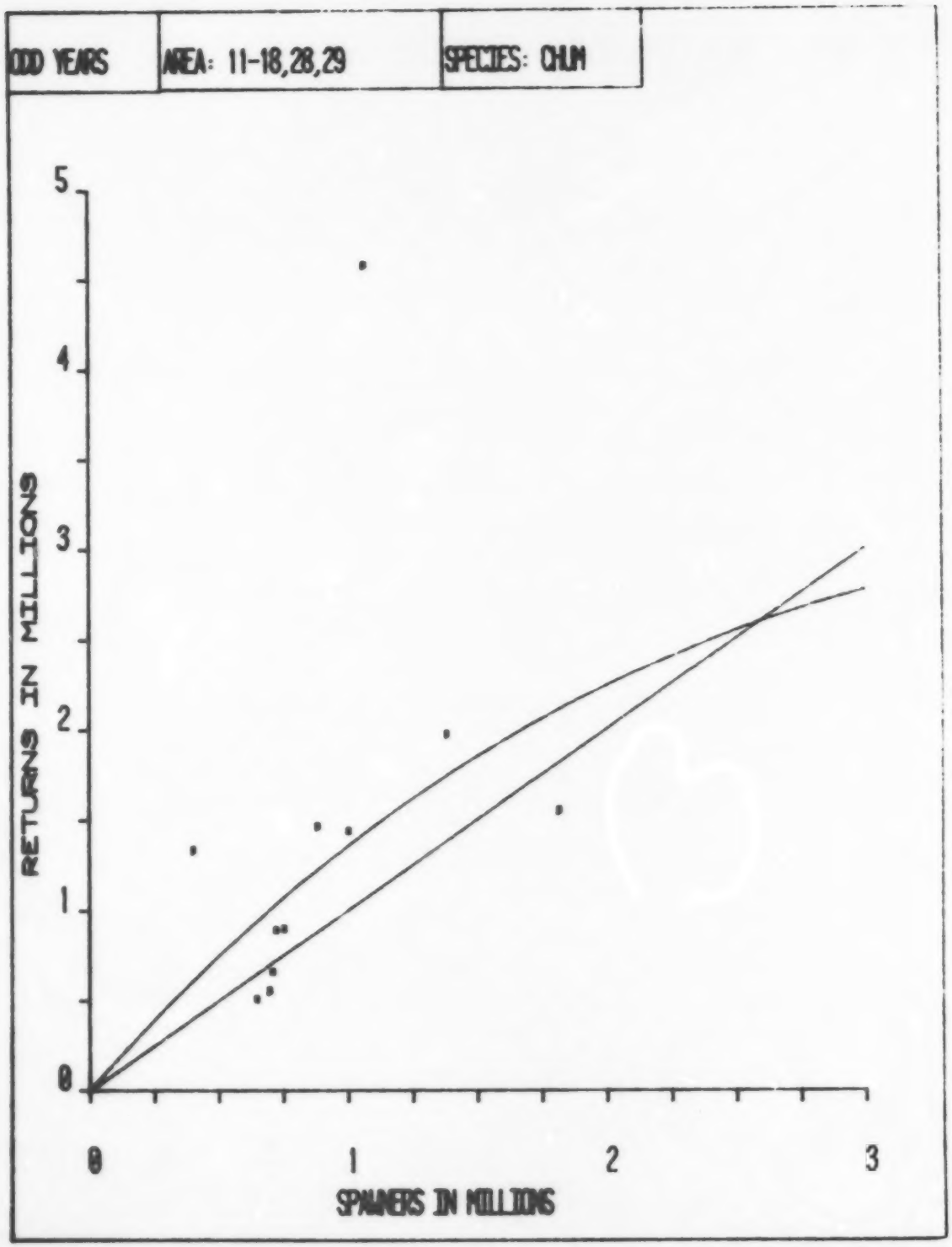

Fig. 56. Stock and recruitment curves for odd broodyears 1957-1977 of Fraser River chum salmon.

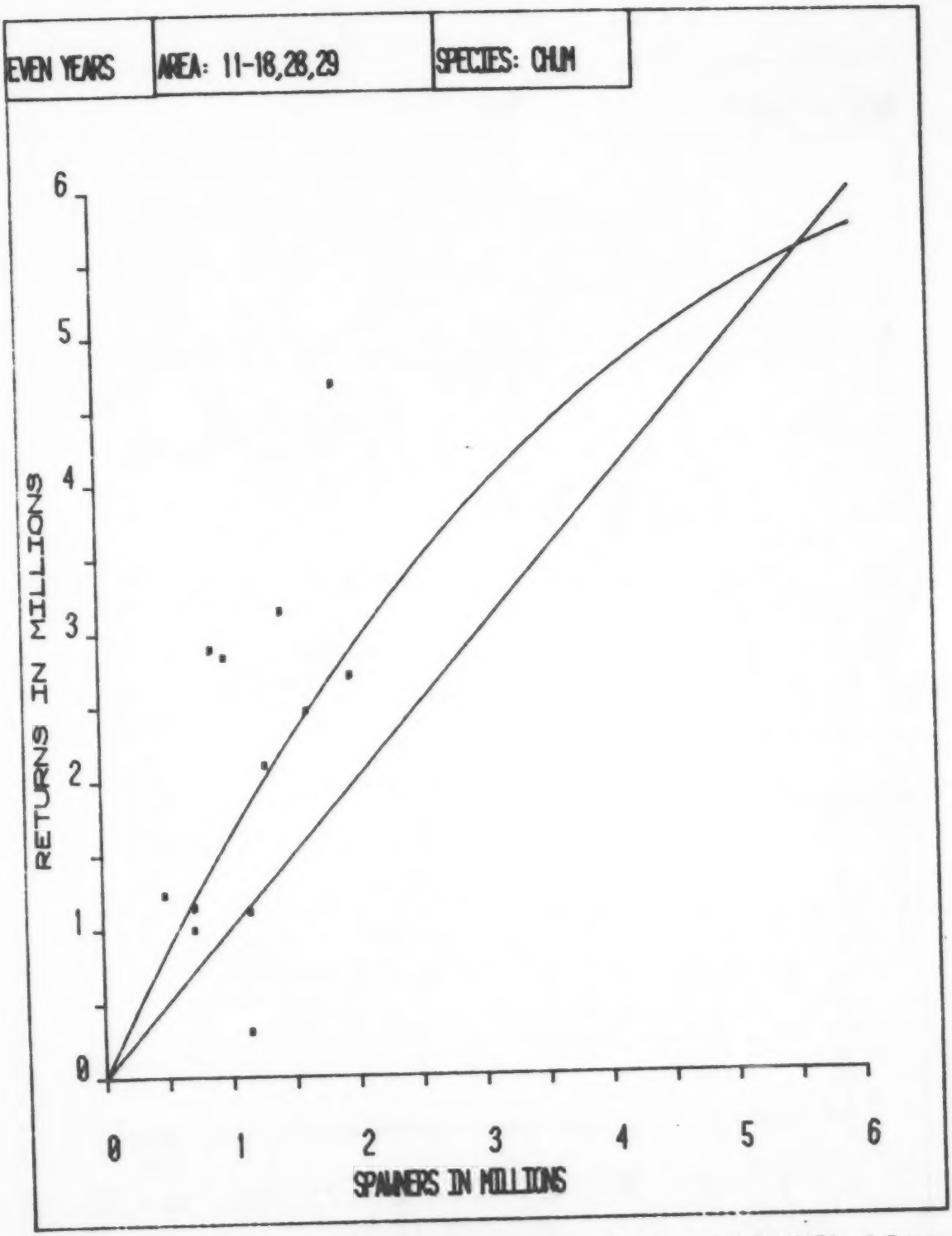

Fig. 57. Stock and recruitment curves for even broodyears 1956-1976 of Fraser River chum salmon.

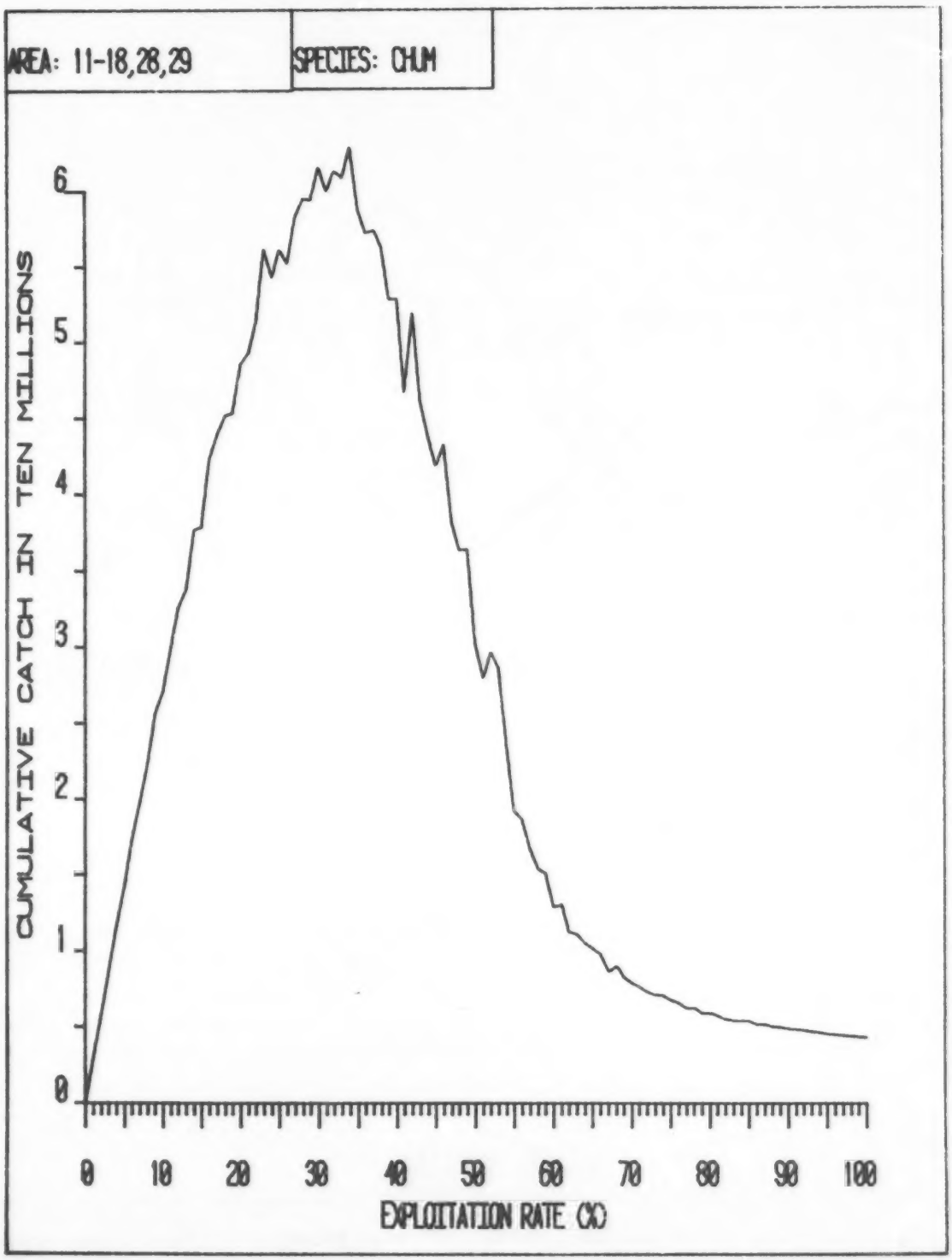

Fig. 58. Projected cumulative yield during 1960-2020 by harvesting at constant exploitation rate in each year for Johnstone Strait, Georgia Strait, and Fraser River chum salmon.

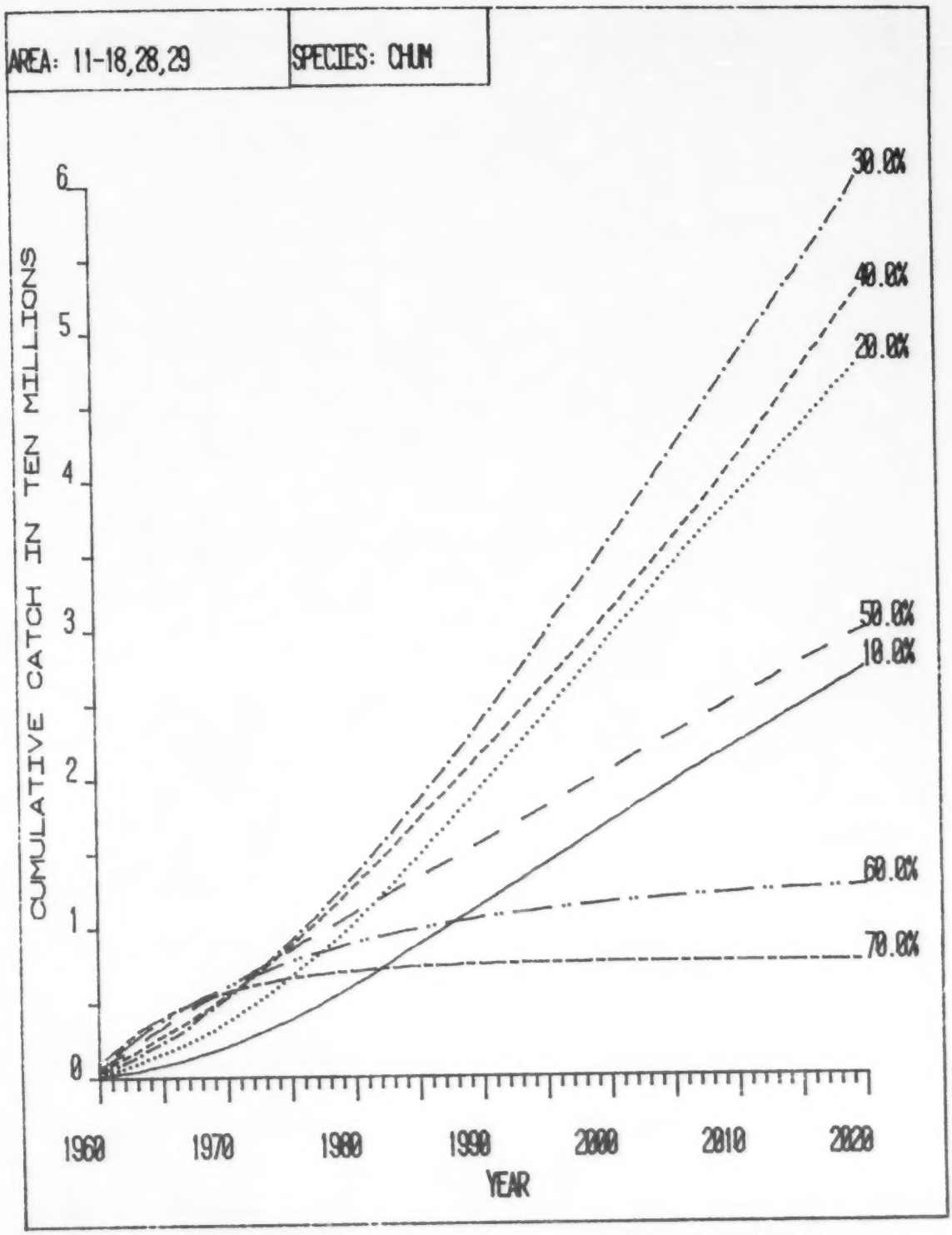

Fig. 59. Summary of yields under a 60-year projection of exploitation rates of 10-70% for Johnstone Strait, Georgia Strait, and Fraser River chum salmon.

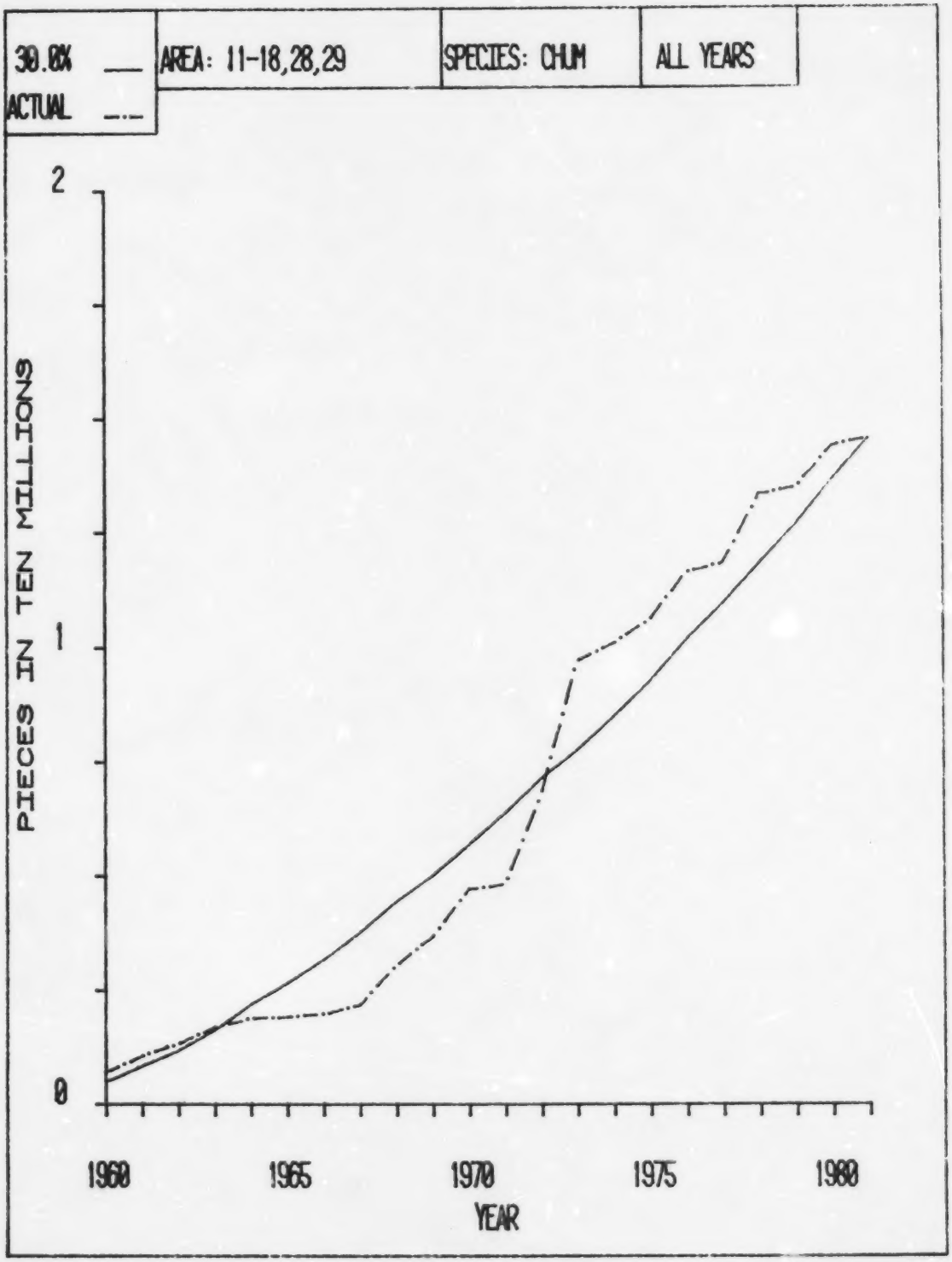

Fig. 60. Actual cumulative catch and projected cumulative catch under a policy of 30% annual exploitation rate during 1960-1981 of Johnstone Strait, Georgia Strait, and Fraser River chum salmon.

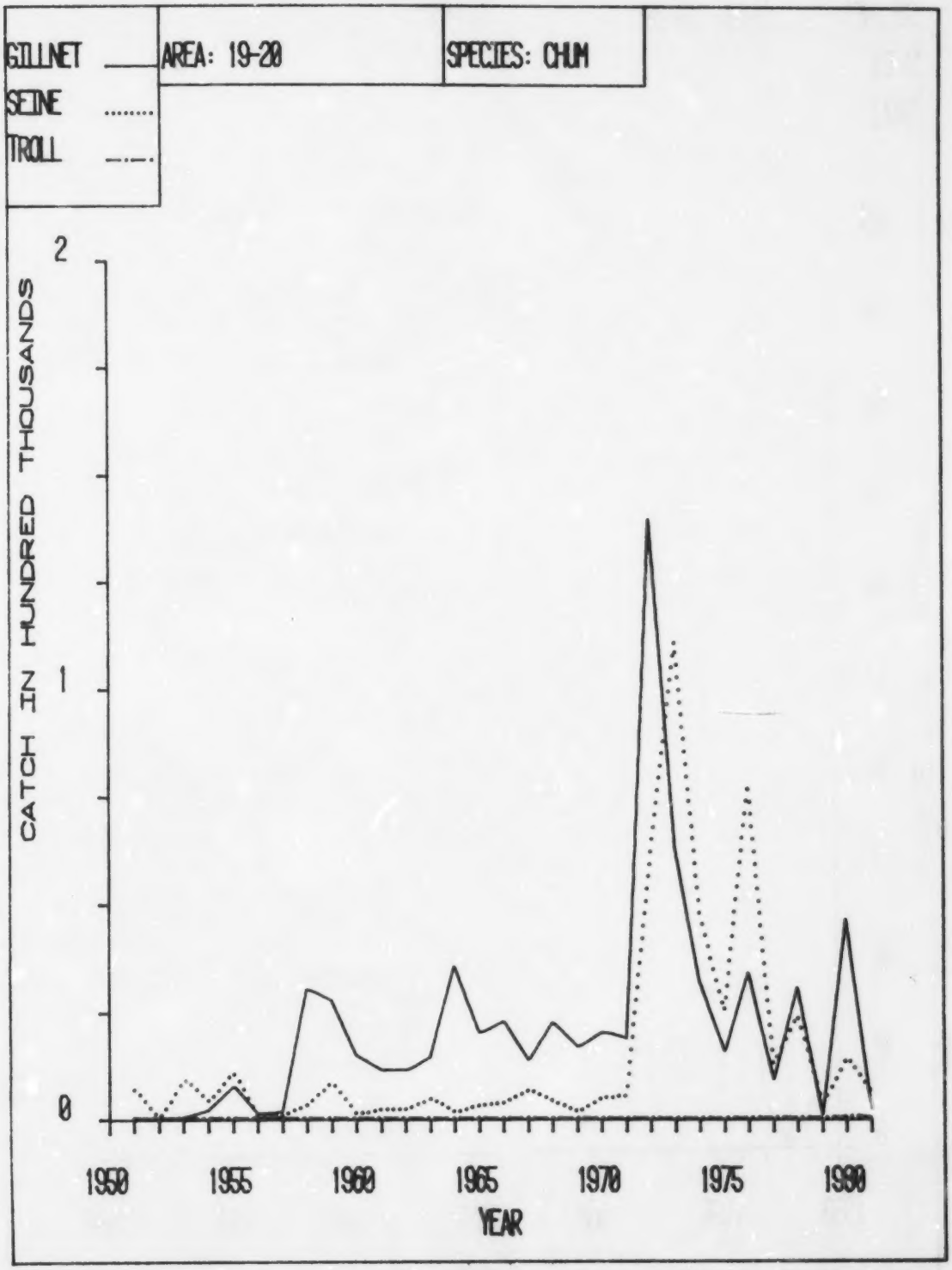

Fig. 61. Percent of total catch by gear of chum salmon in Statistical Areas 19-20.

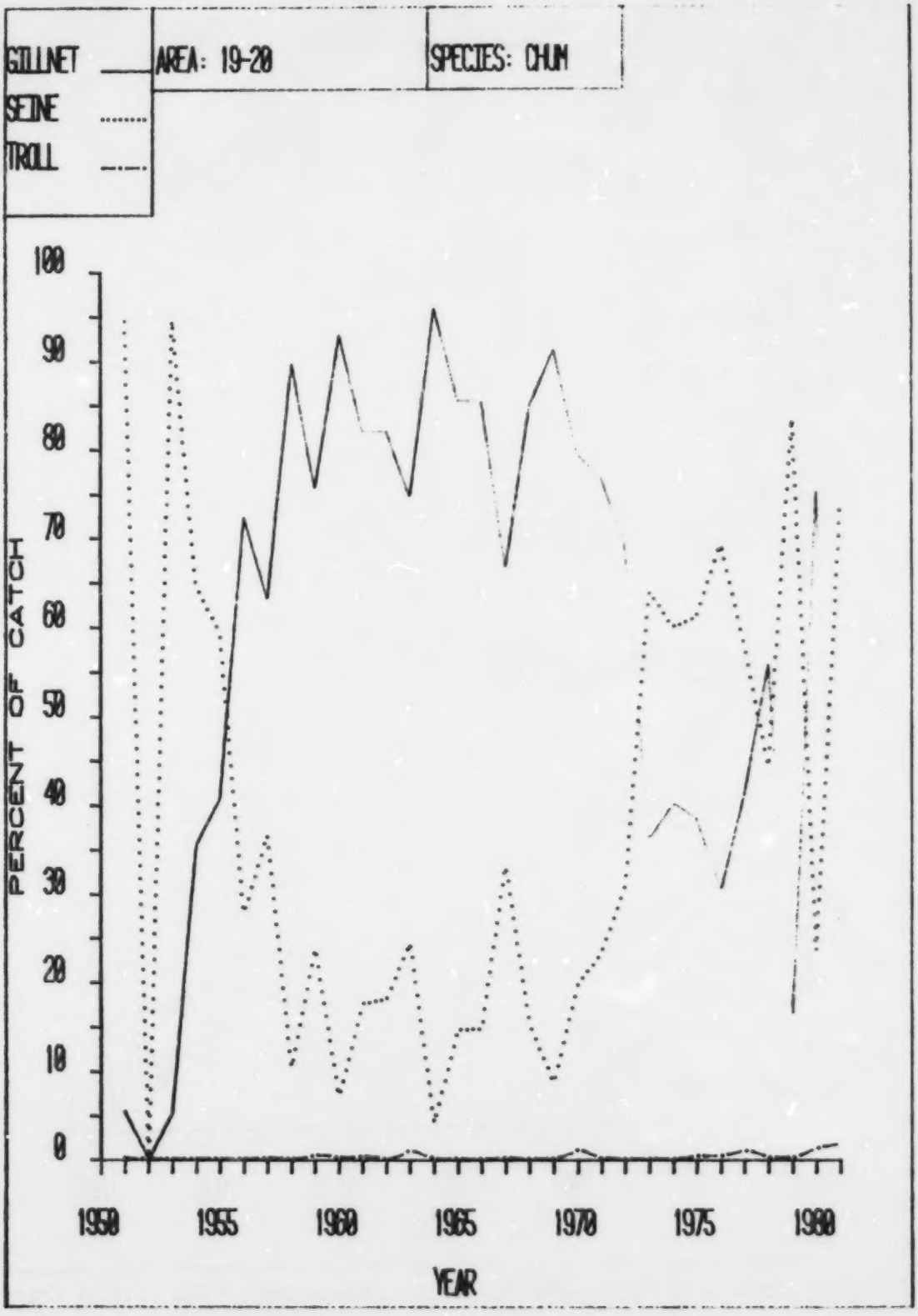

Fig. 62. Percent of total catch by gear of chum salmon in Statistical Areas 19-20.

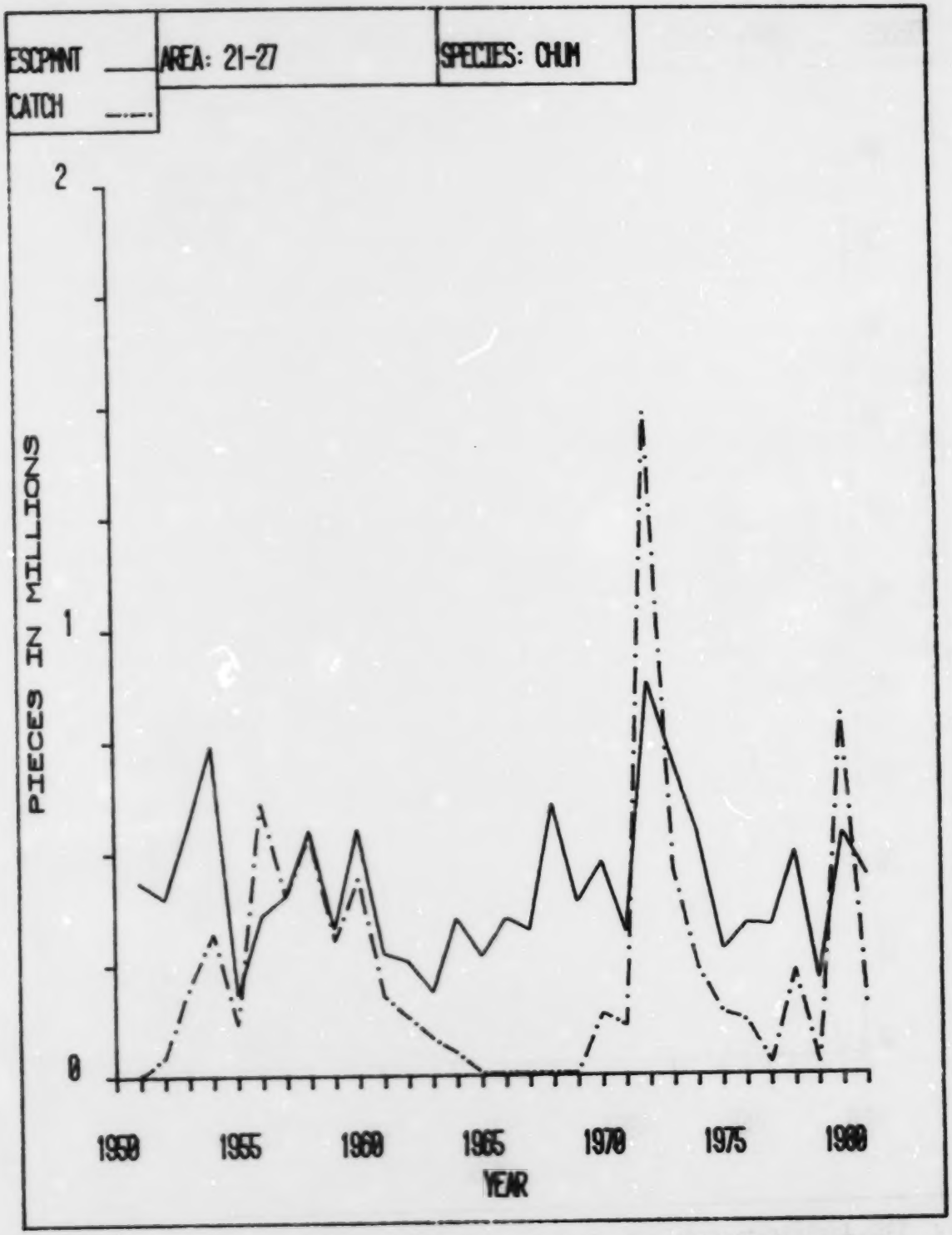

Fig. 63. Catch and escapement of West Coast Vancouver Island chum salmon.

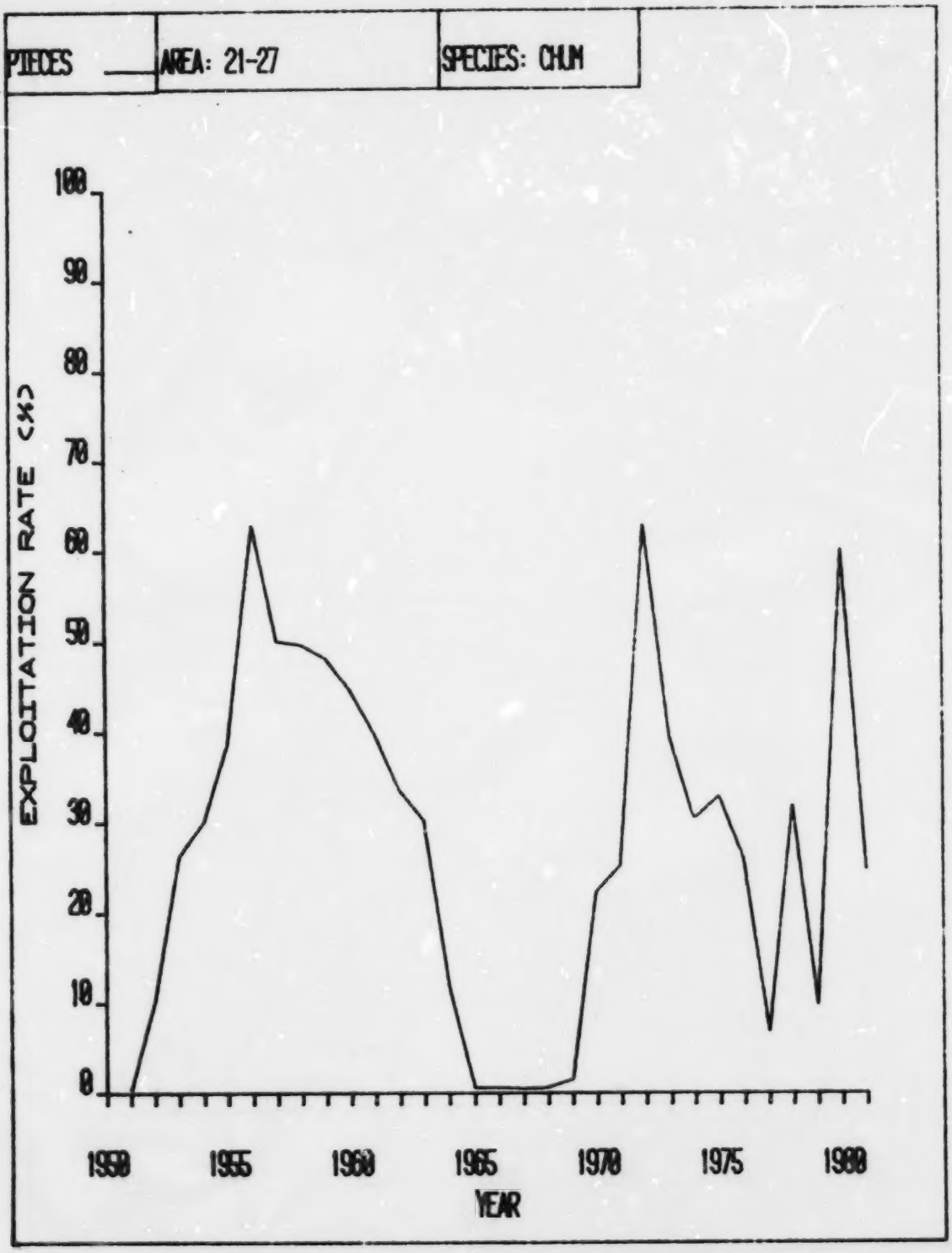

Fig. 64. Exploitation rate of West Coast Vancouver Island chum salmon.

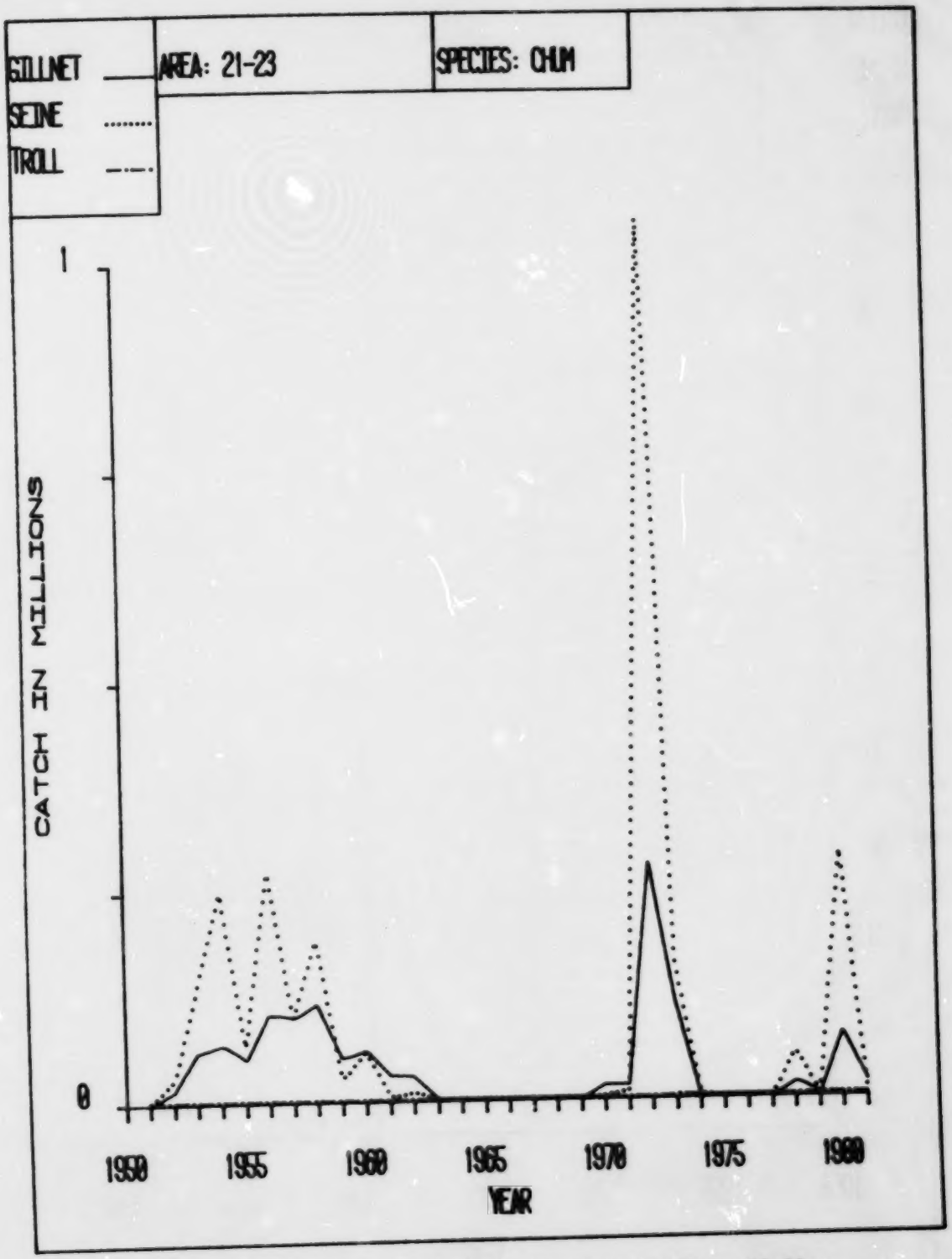

Fig. 65. Catch by gear of chum salmon in Statistical Areas 23-23.

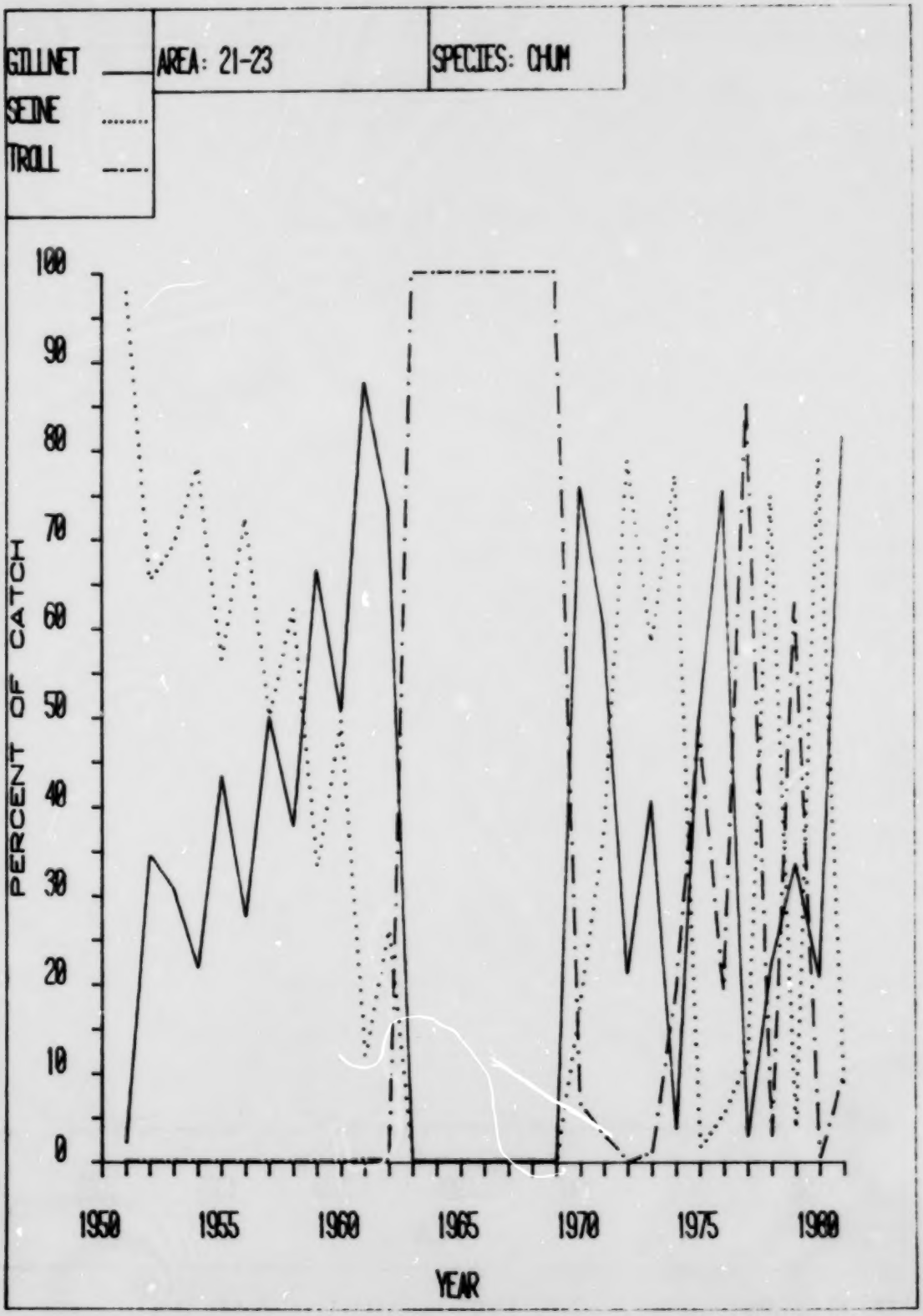

Fig. 66. Percent of total catch by gear of chum salmon in Statistical Areas 21-23.

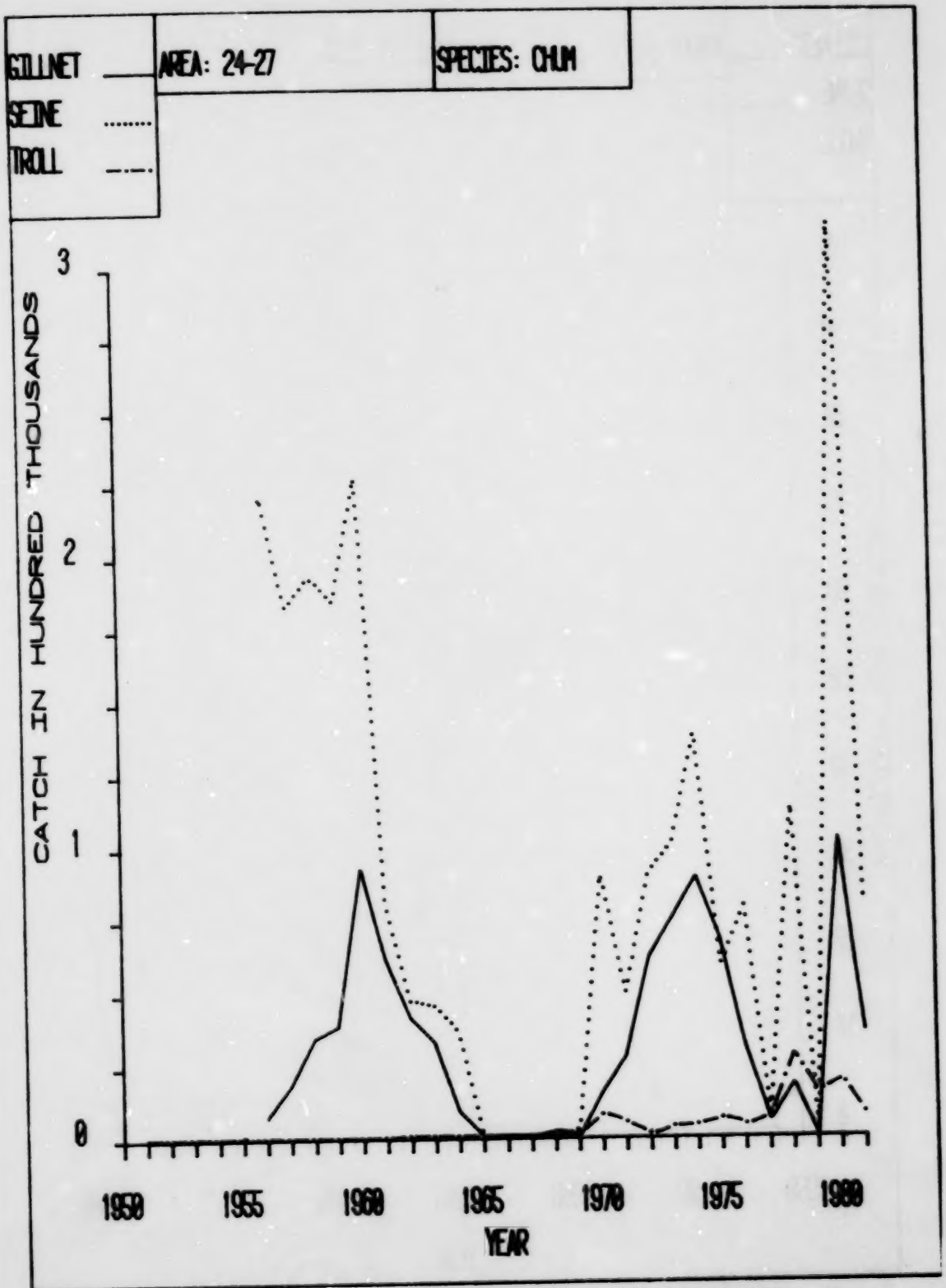

Fig. 67. Catch by gear of chum salmon in Statistical Area 24-27.

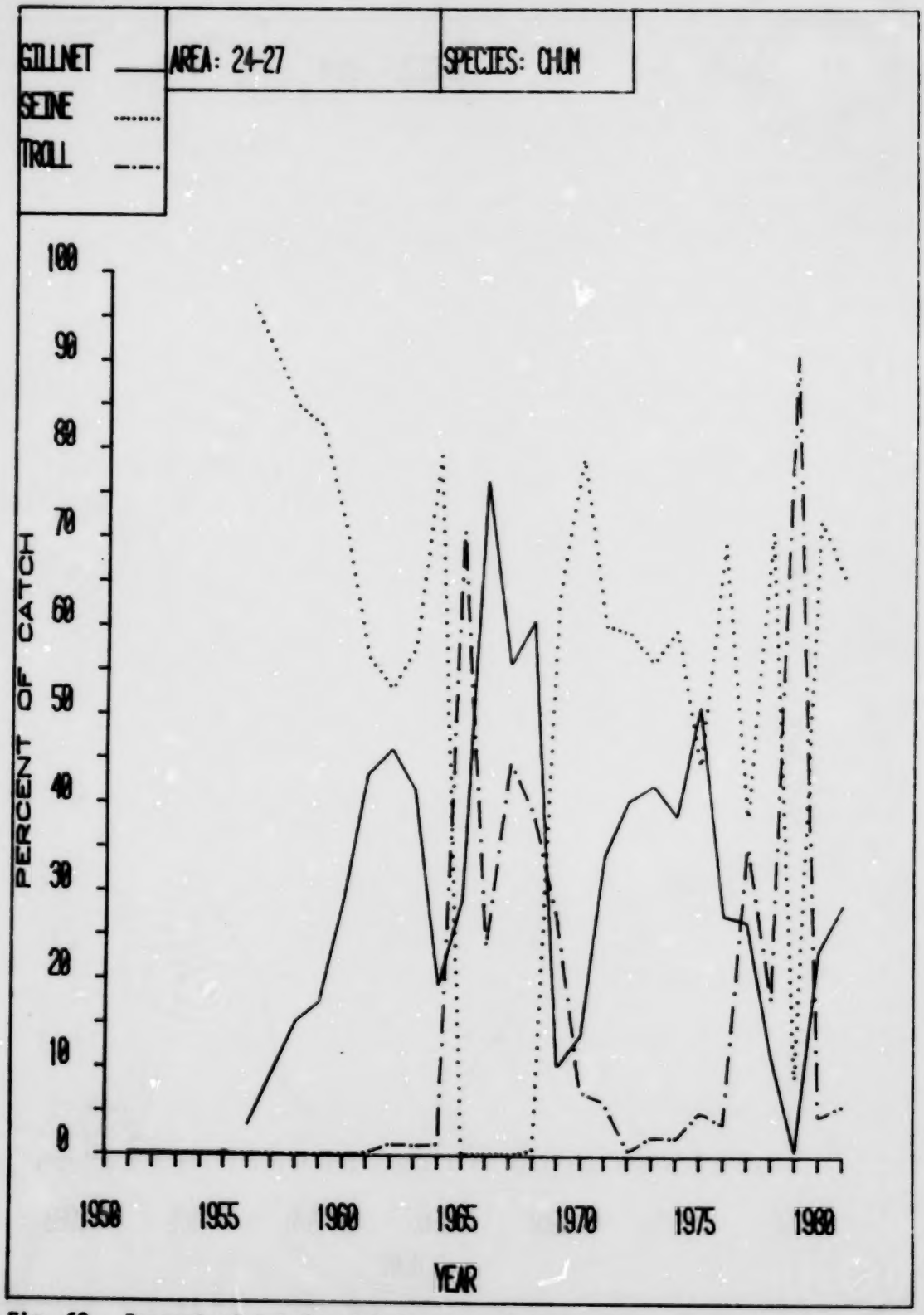

Fig. 68. Percent of total catch by gear of chum salmon in Statistical Areas 24-27.

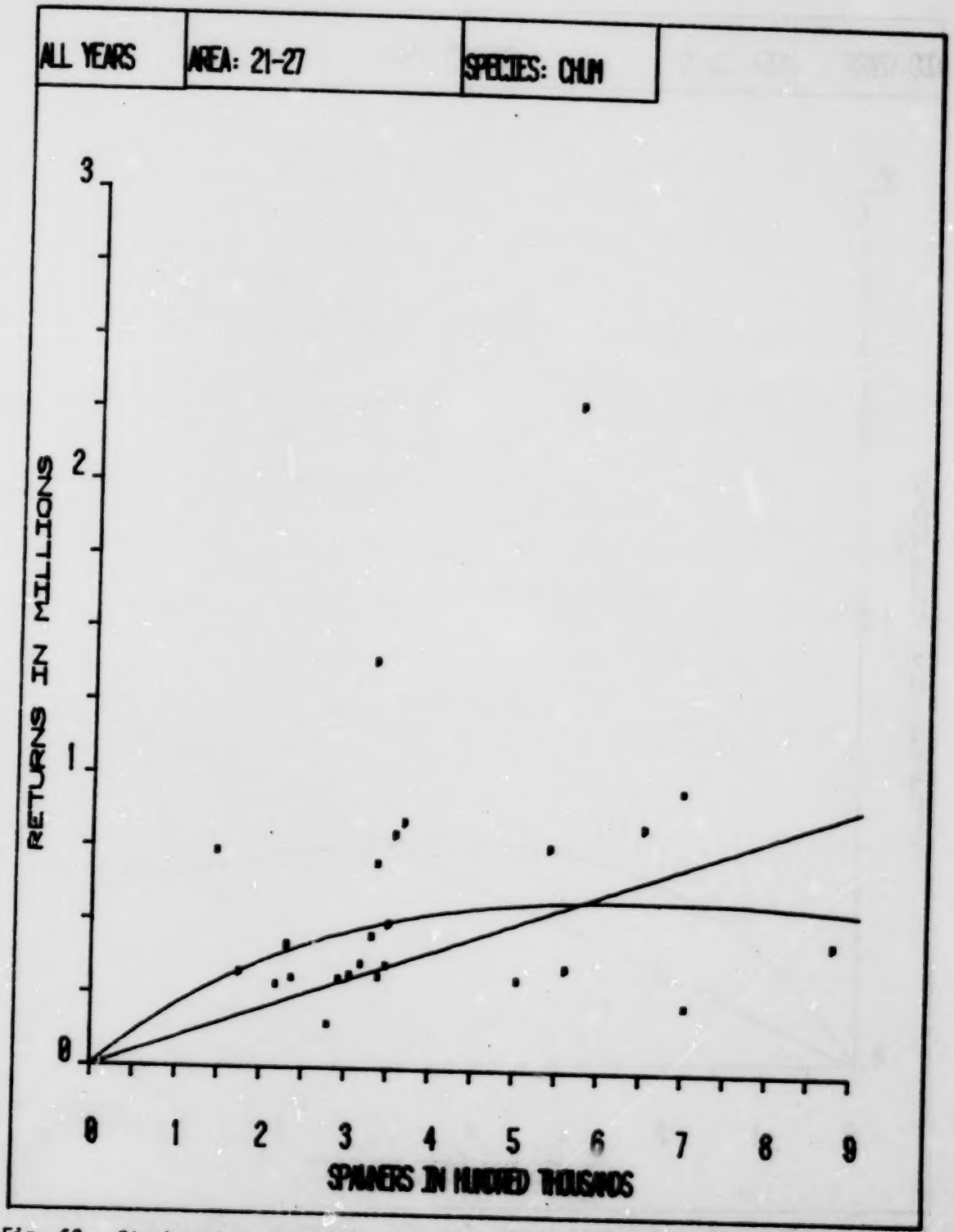

Fig. 69. Stock and recruitment curves for 1953-1977 broodyears of West Coast Vancouver Island chum salmon.

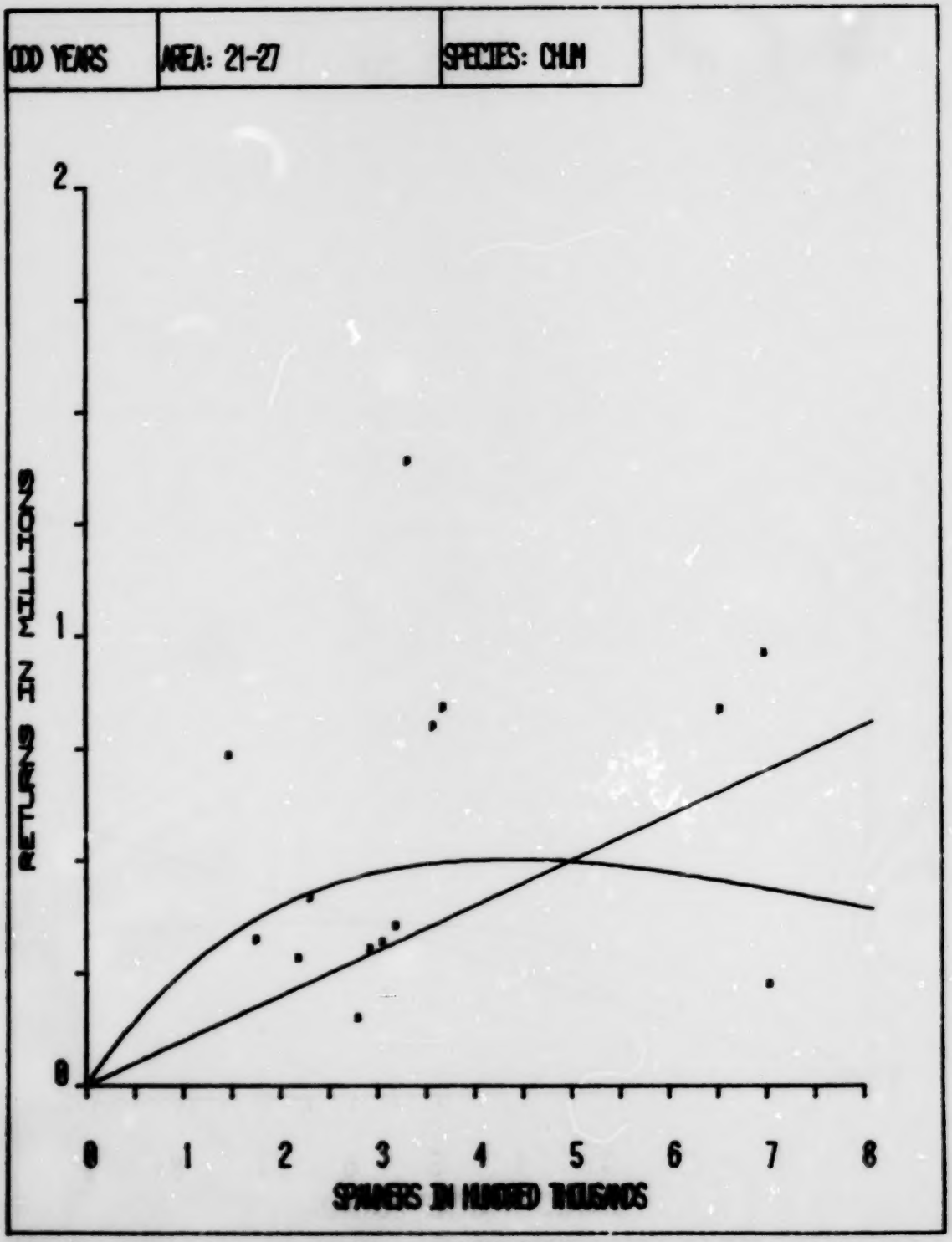

Fig. 70. Stock and recruitment curves for odd broodyears 1953-1977 of West Coast Vancouver Island chum salmon.

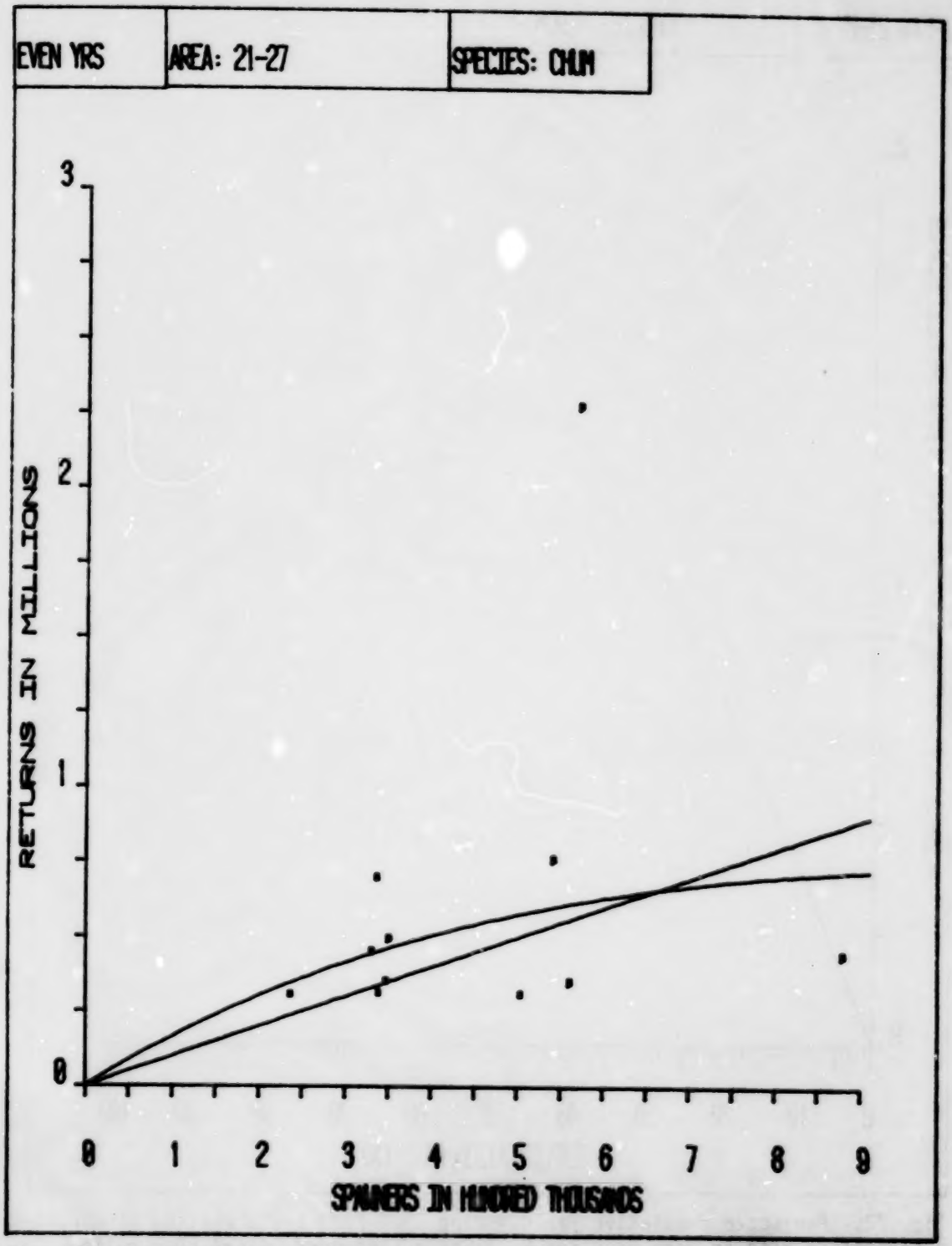

Fig. 71. Stock and recruitment curves for even broodyears 1954-1976 of West Coast Vancouver Island chum salmon.

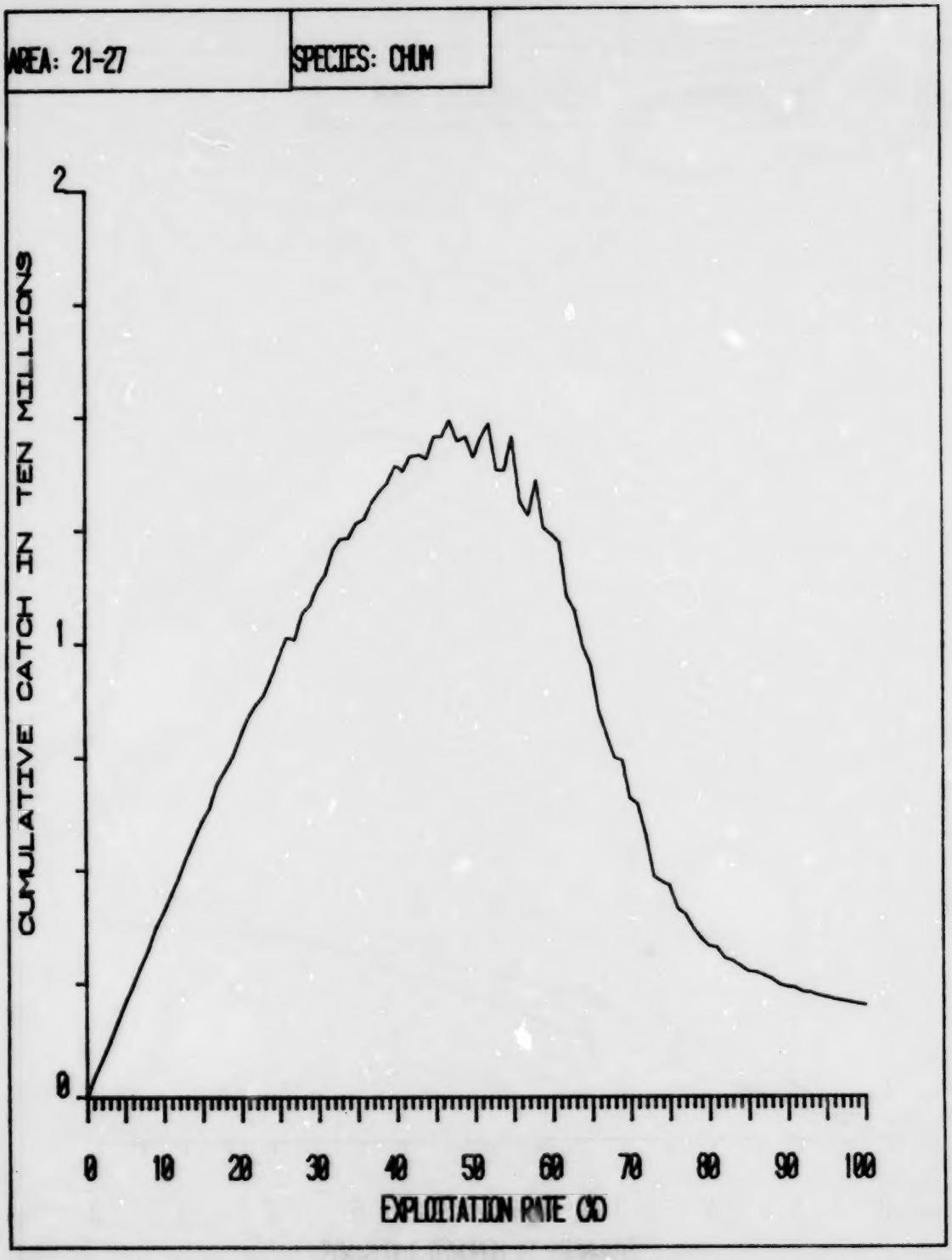

Fig. 72. Projected cumulative yield during 1960-2020 by harvesting at constant exploitation rate in each year for West Coast Vancouver Island chum salmon.

APPENDIX A

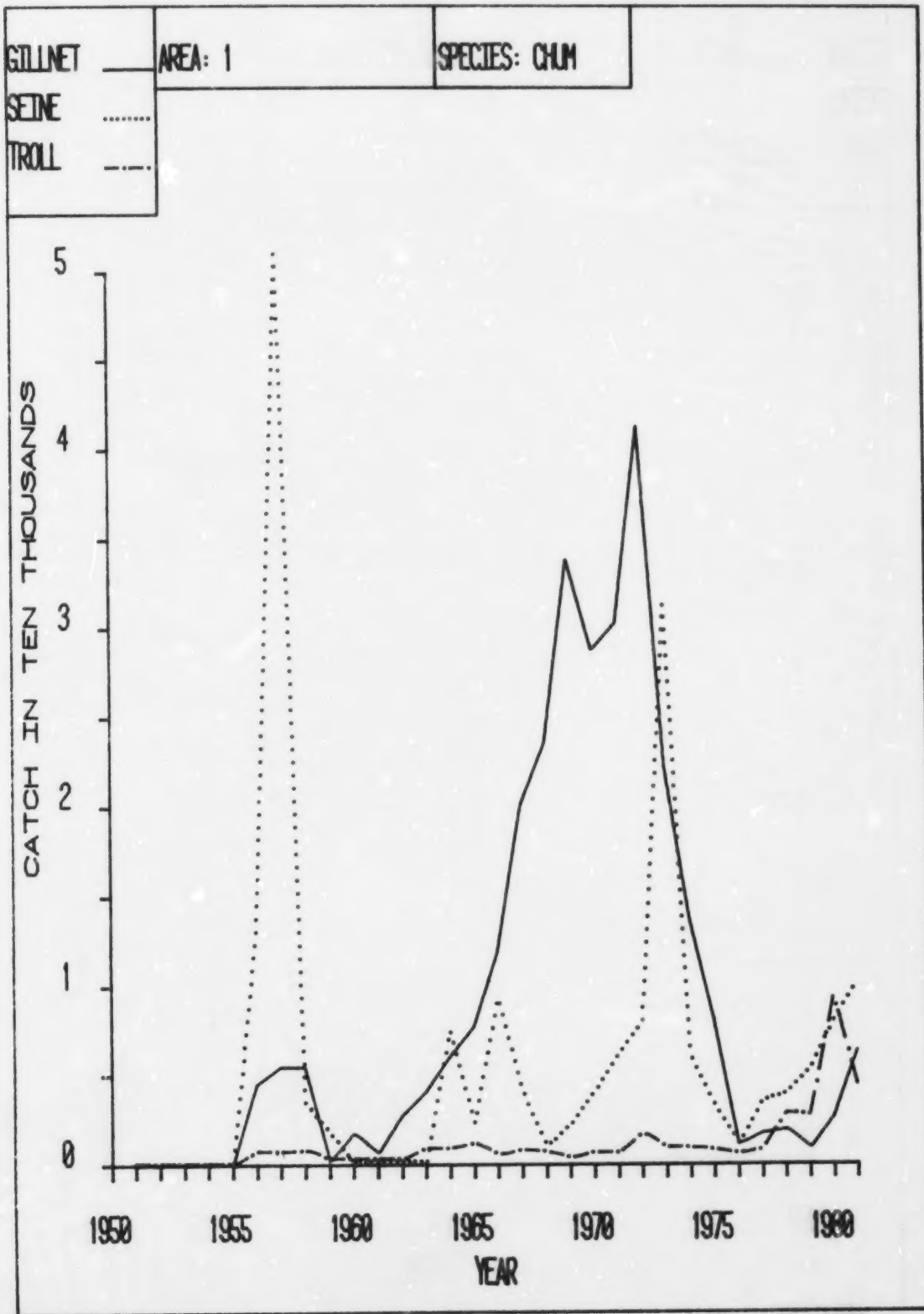

Fig. A1. Catch of chum salmon by gear in Statistical Area 1, 1951-1981.

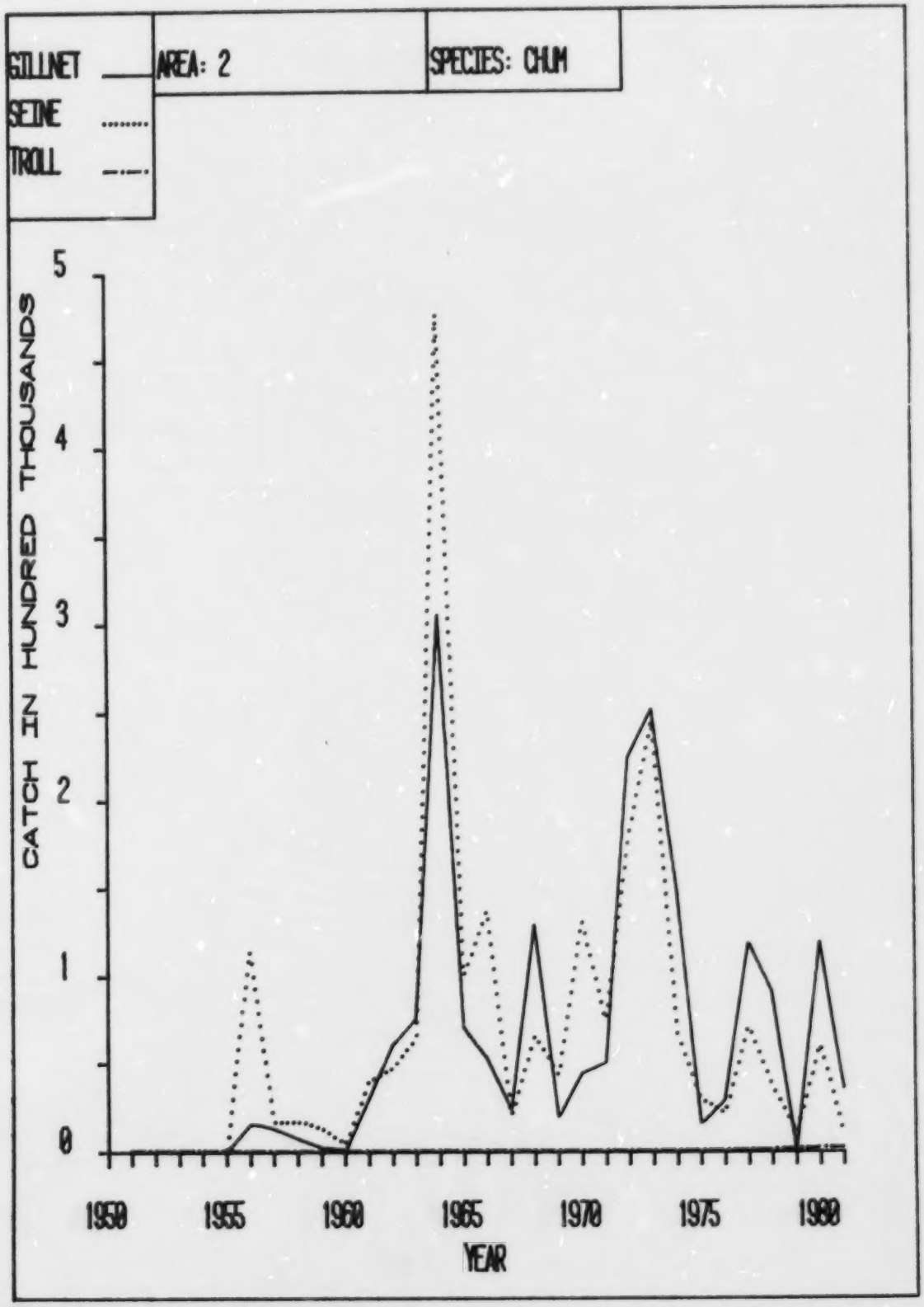

Fig. A2. Catch of chum salmon by gear in Statistical Area 2, 1951-1981.

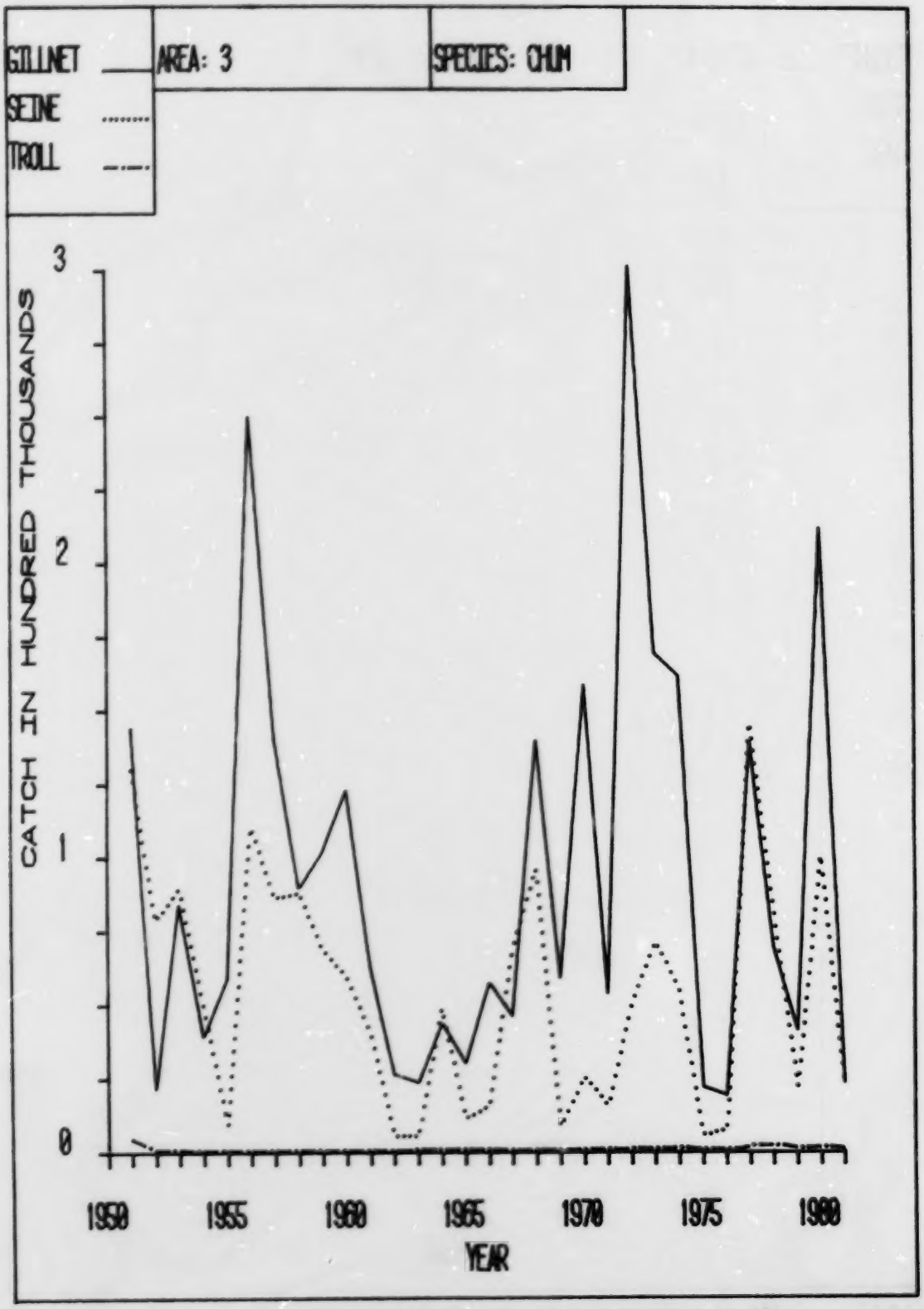

Fig. A3. Catch of chum salmon by gear in Statistical Area 3, 1951-1981.

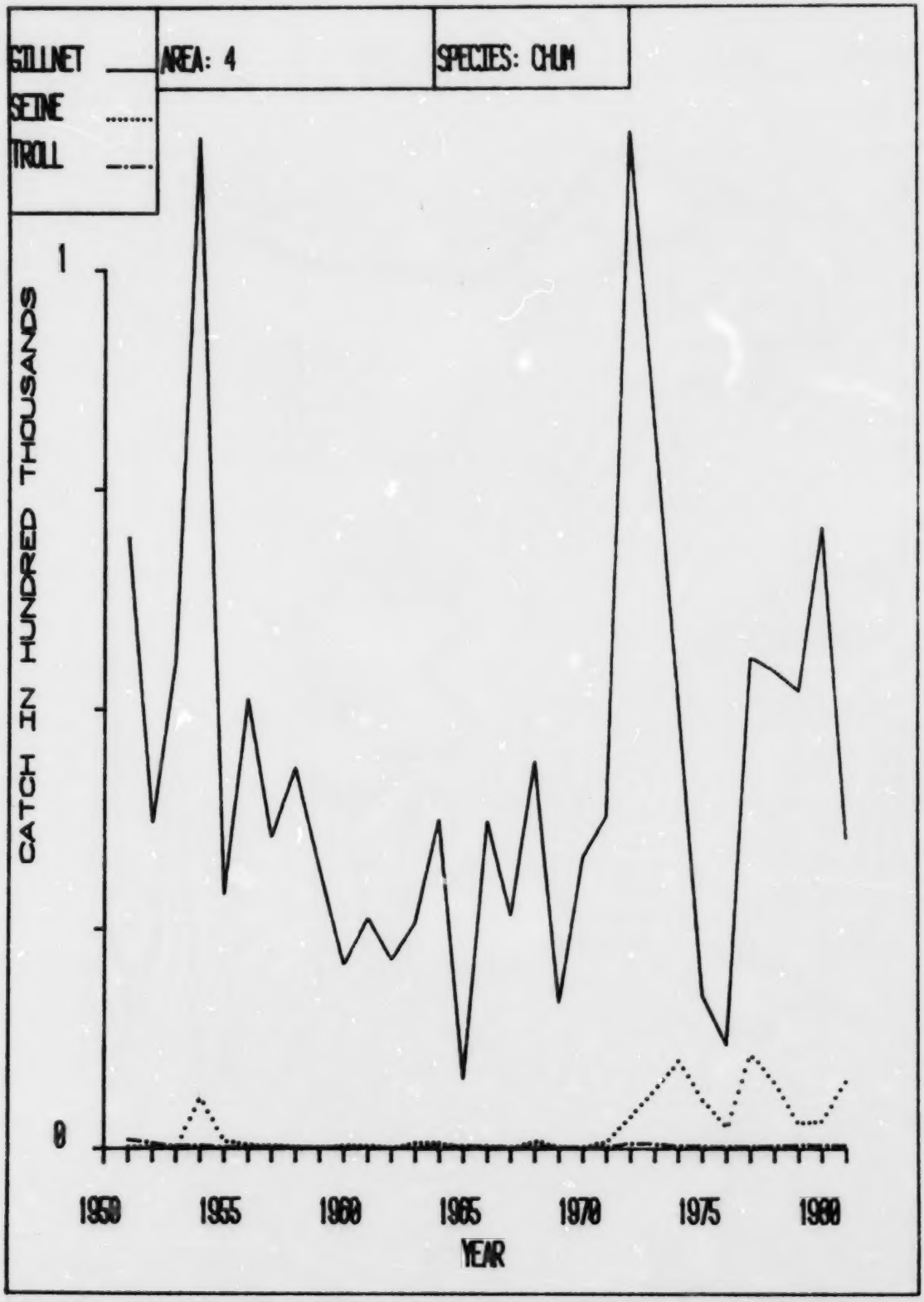

Fig. A4. Catch of chum salmon by gear in Statistical Area 4, 1951-1981.

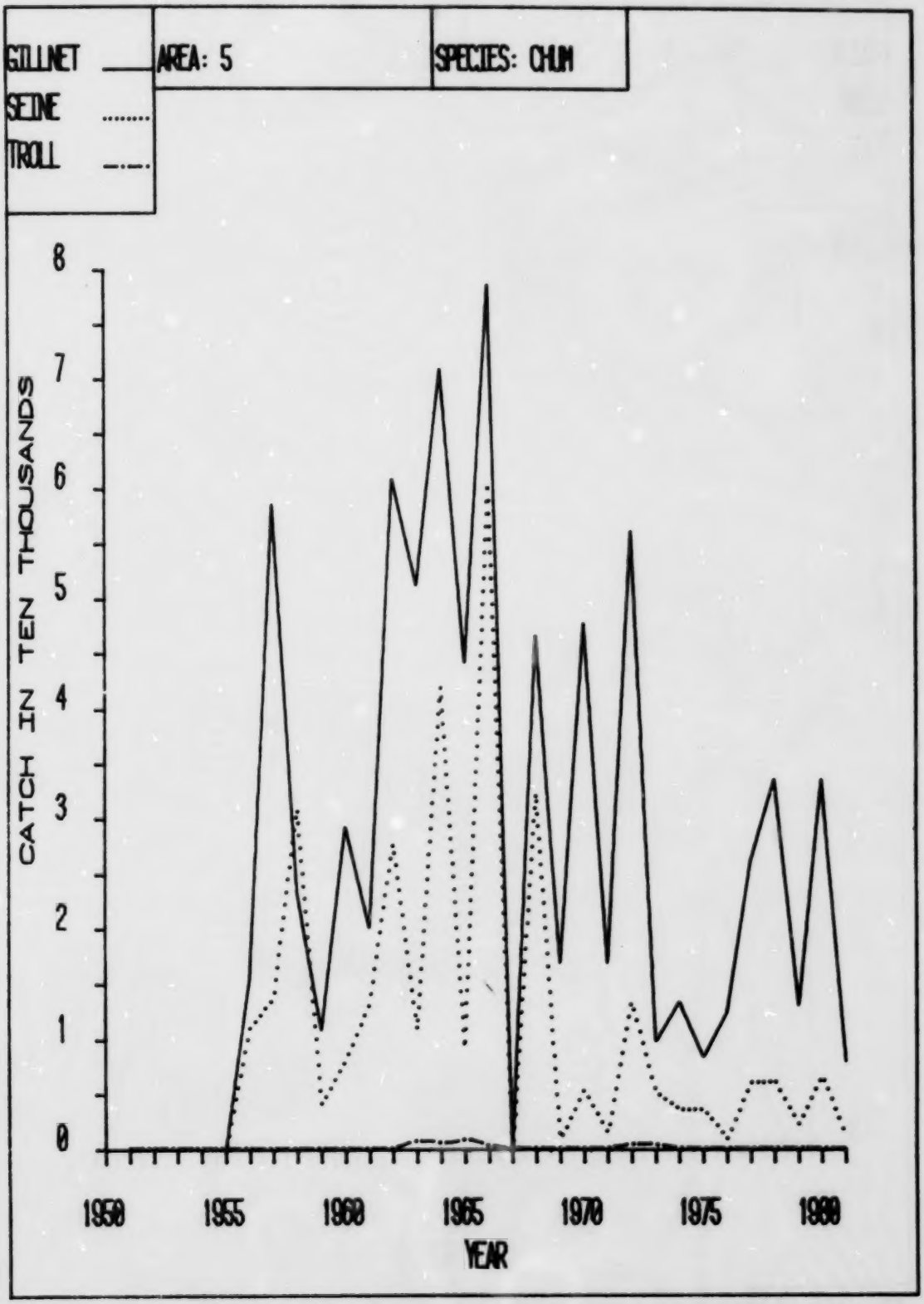

Fig. A5. Catch of chum salmon by gear in Statistical Area 5, 1951-1981.

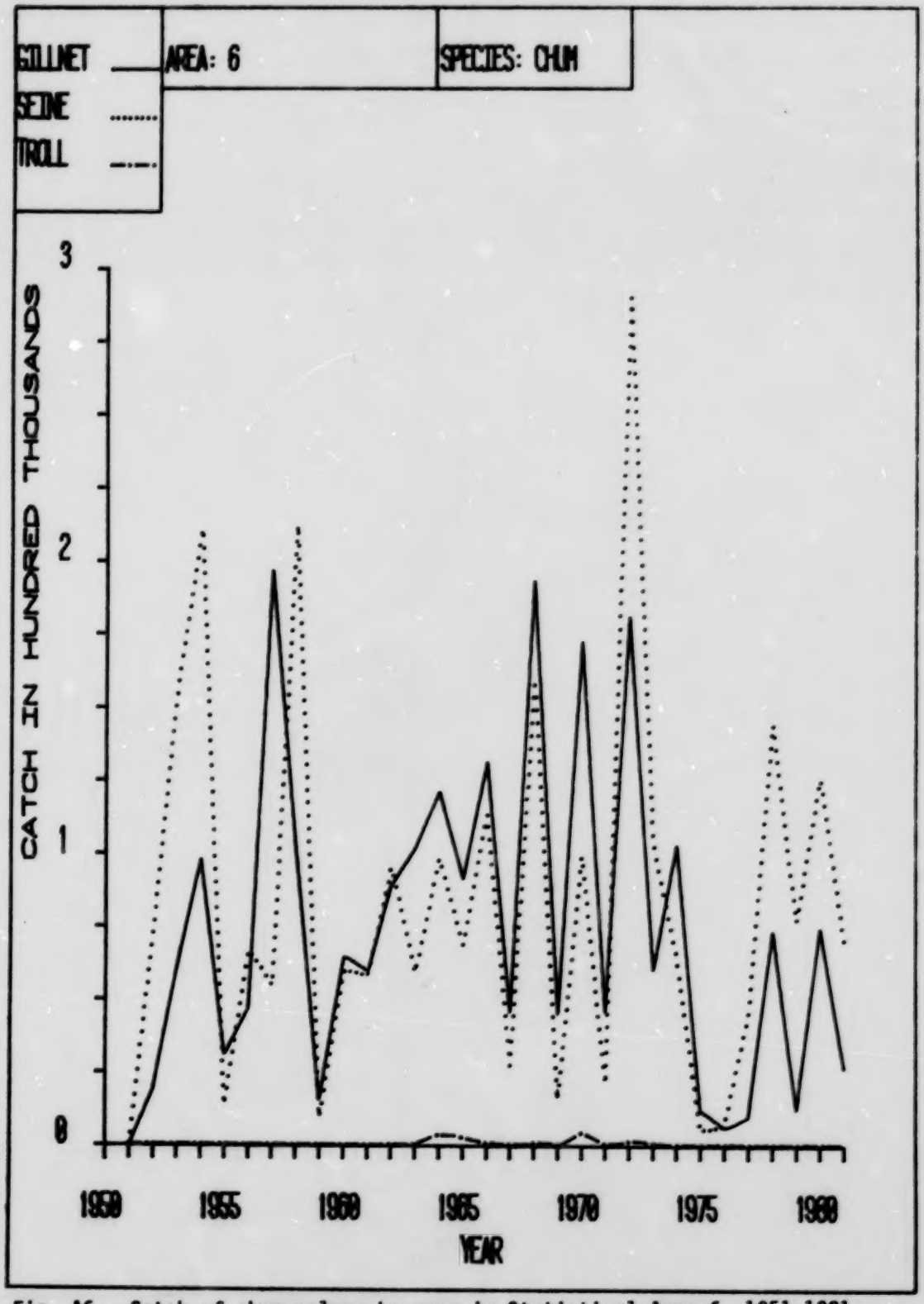

Fig. A6. Catch of chum salmon by gear in Statistical Area 6, 1951-1981.

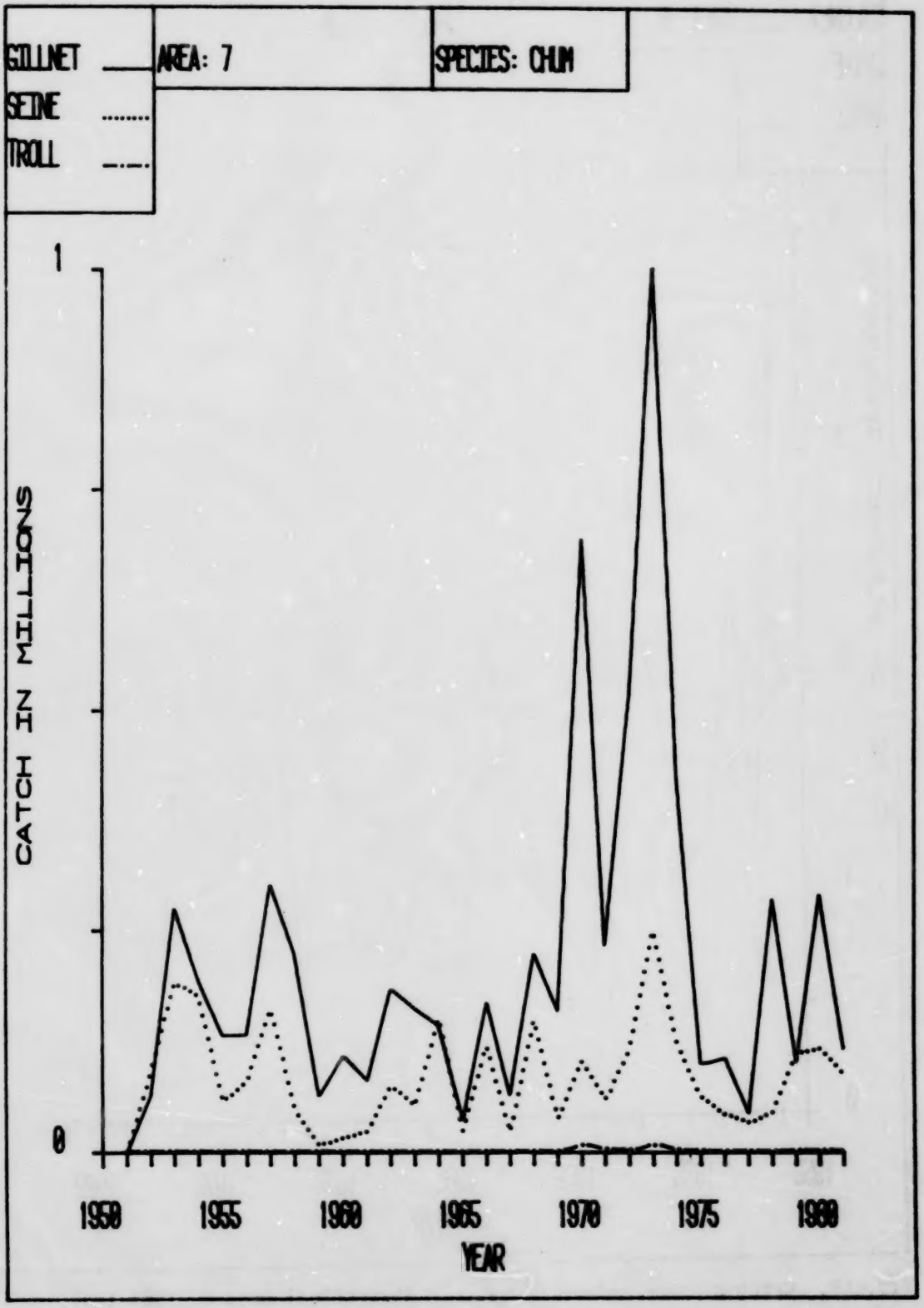

Fig. A7. Catch of chum salmon by gear in Statistical Area 8, 1951-81.

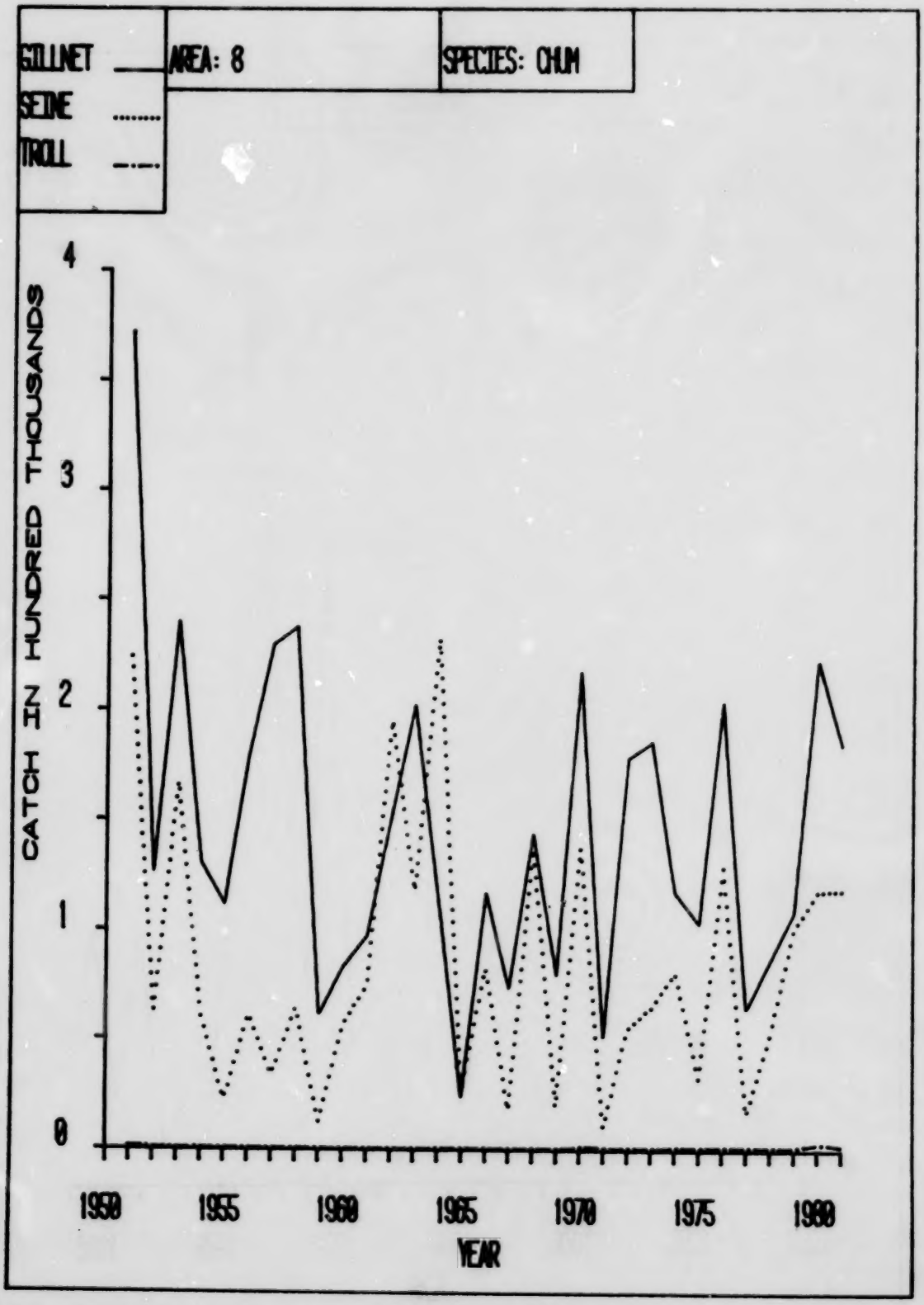

Fig. A8. Catch of chum salmon by gear in Statistical Area 8, 1951-1981.

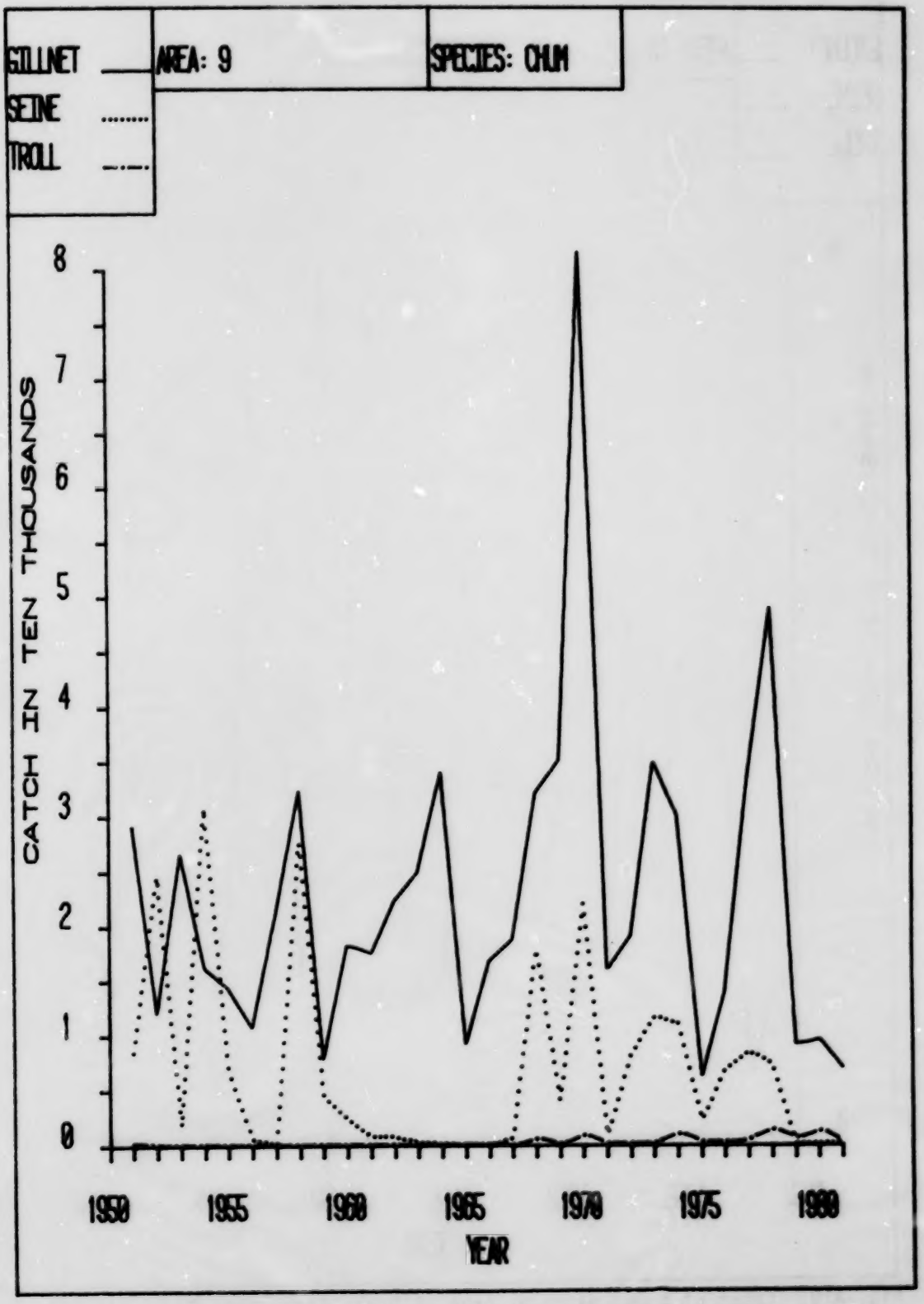

Fig. A9. Catch of chum salmon by gear in Statistical Area 9, 1951-1981.

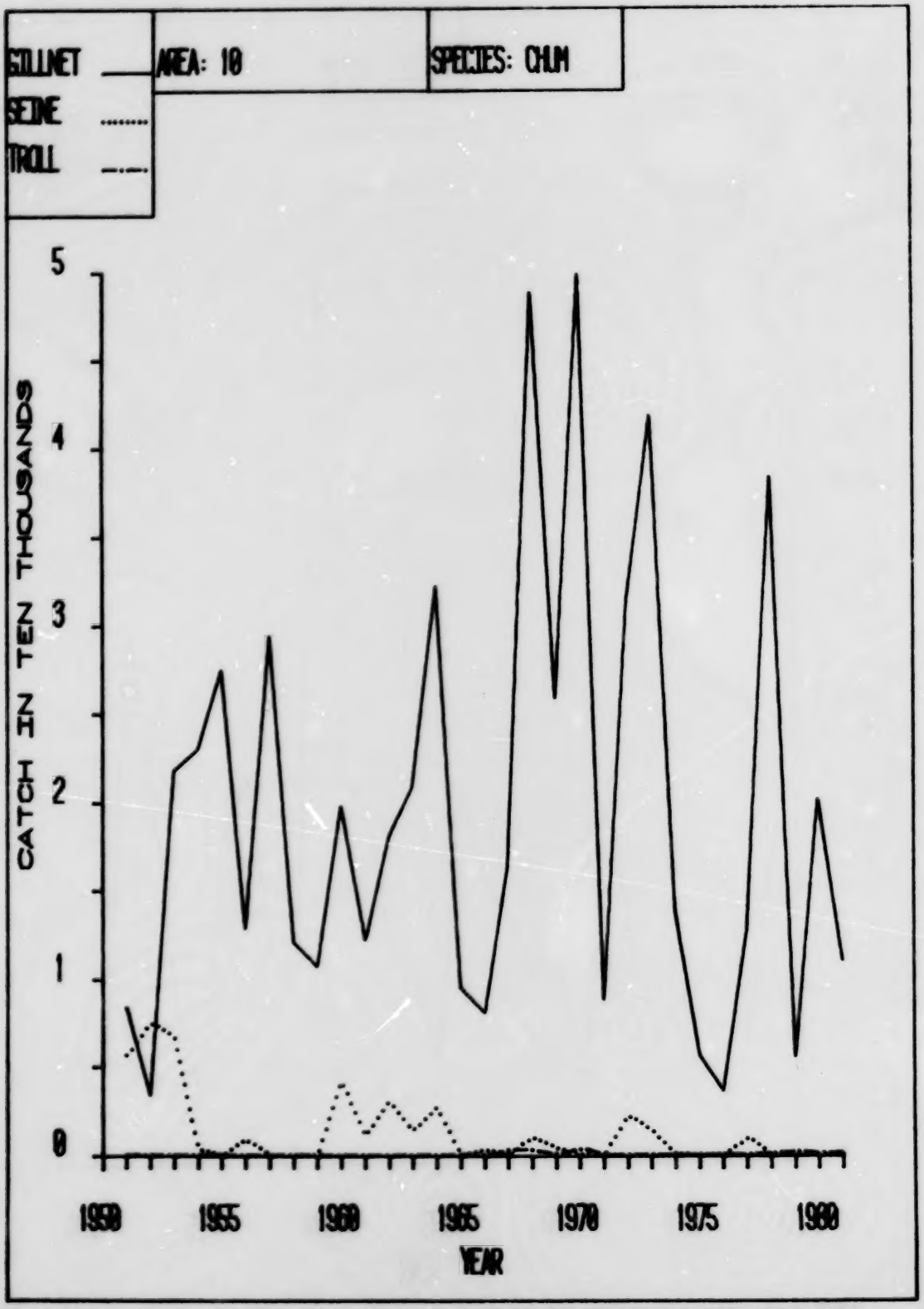

Fig. A10. Catch of chum salmon by gear in Statistical Area 10, 1951-1981.

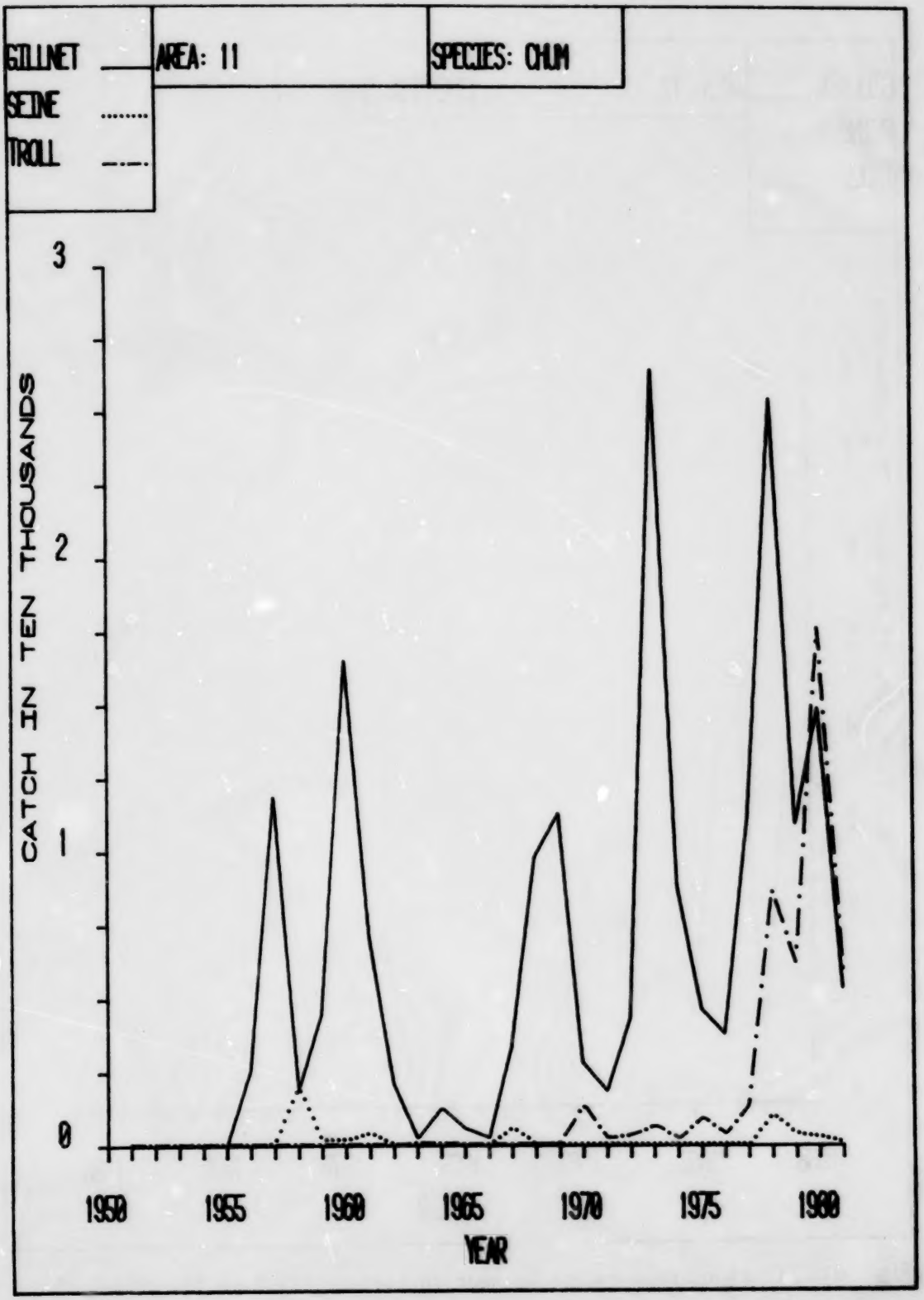

Fig. A11. Catch of chum salmon by gear in Statistical Area 11, 1951-1981.

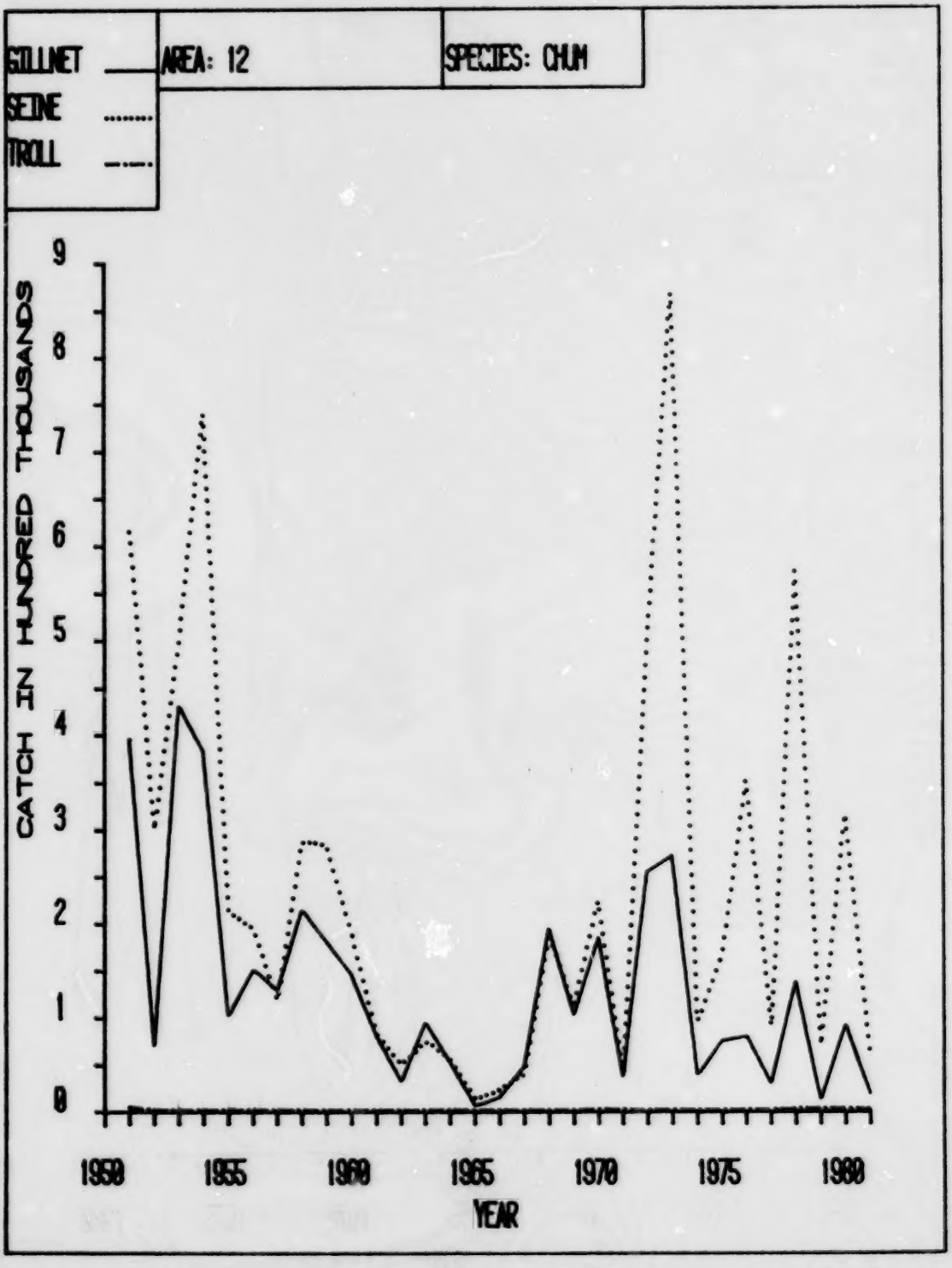

Fig. A12. Catch of chum salmon by gear in Statistical Area 12, 1951-1981.

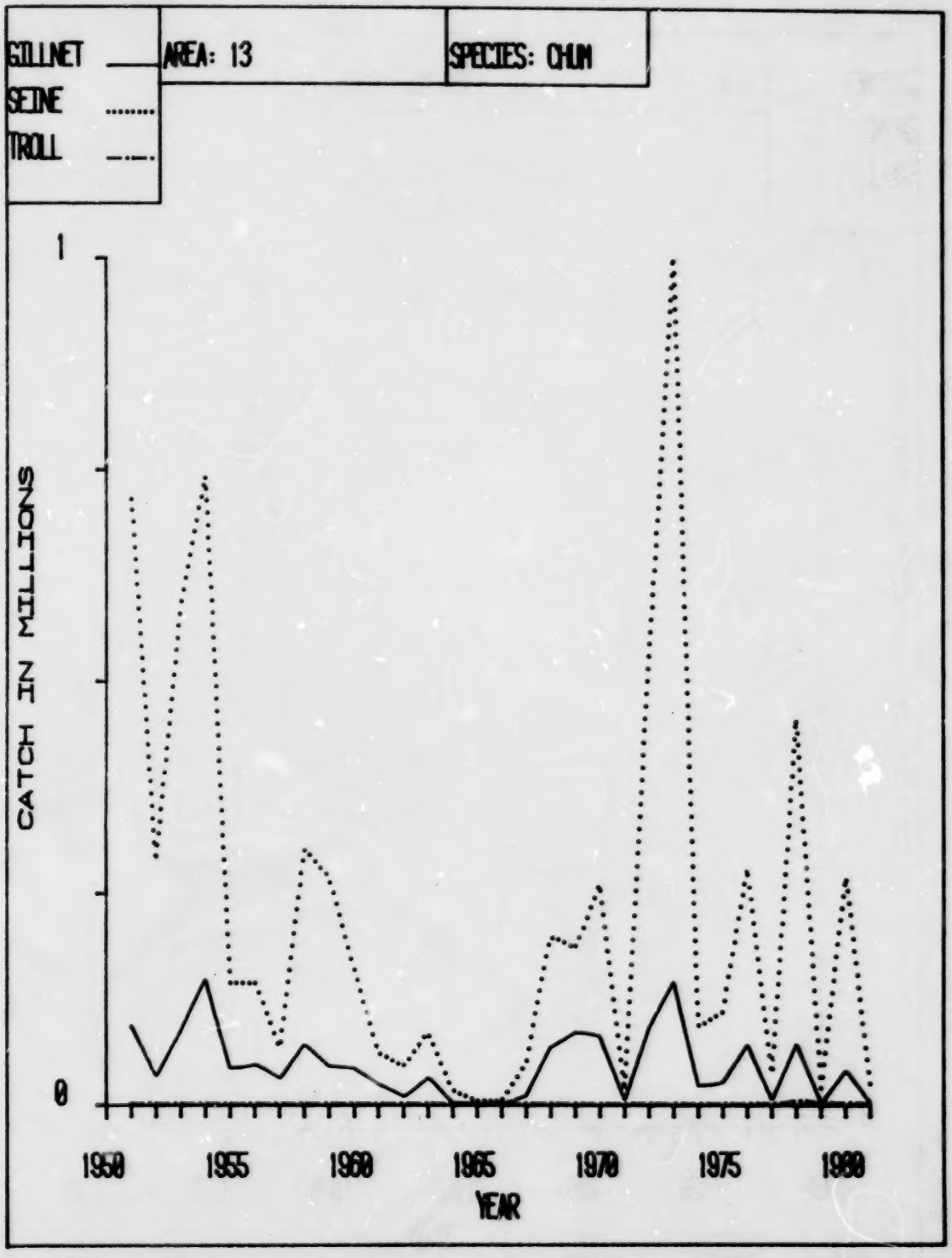

Fig. A13. Catch of chum salmon by gear in Statistical Area 13, 1951-1981.

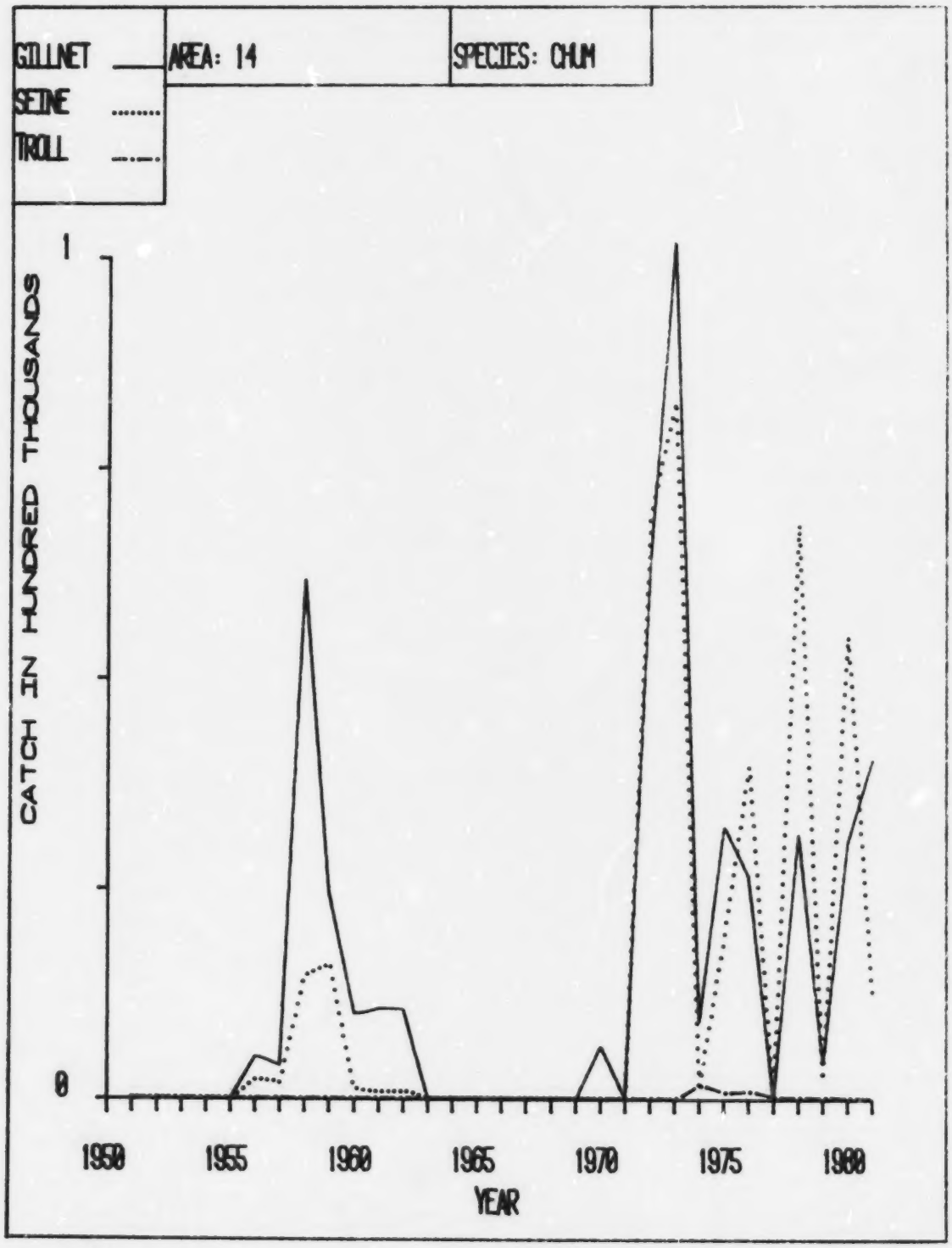

Fig. A14. Catch of chum salmon by gear in Statistical Area 14, 1951-1981.

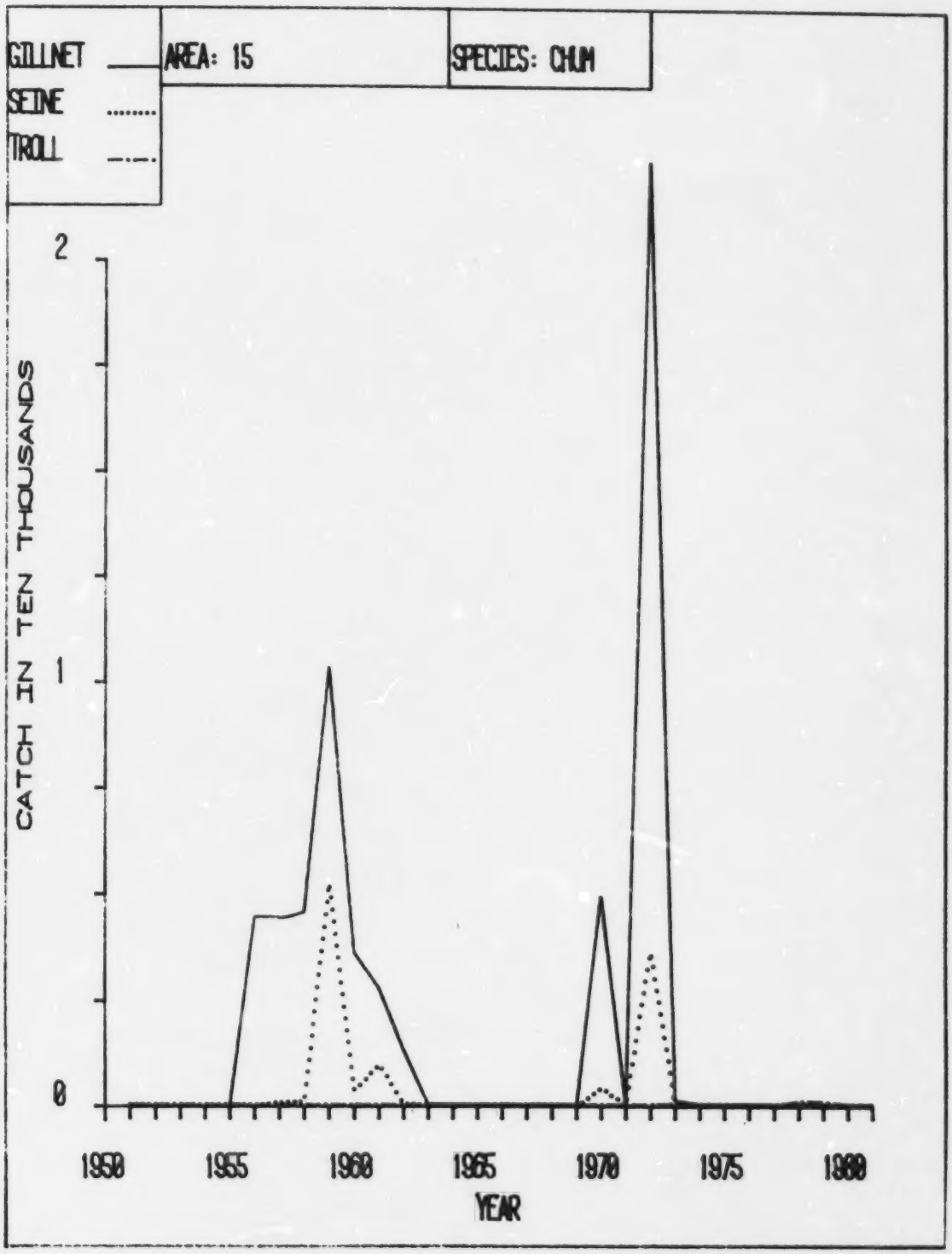

Fig. A15. Catch of chum salmon by gear in Statistical Area 15, 1951-1981.

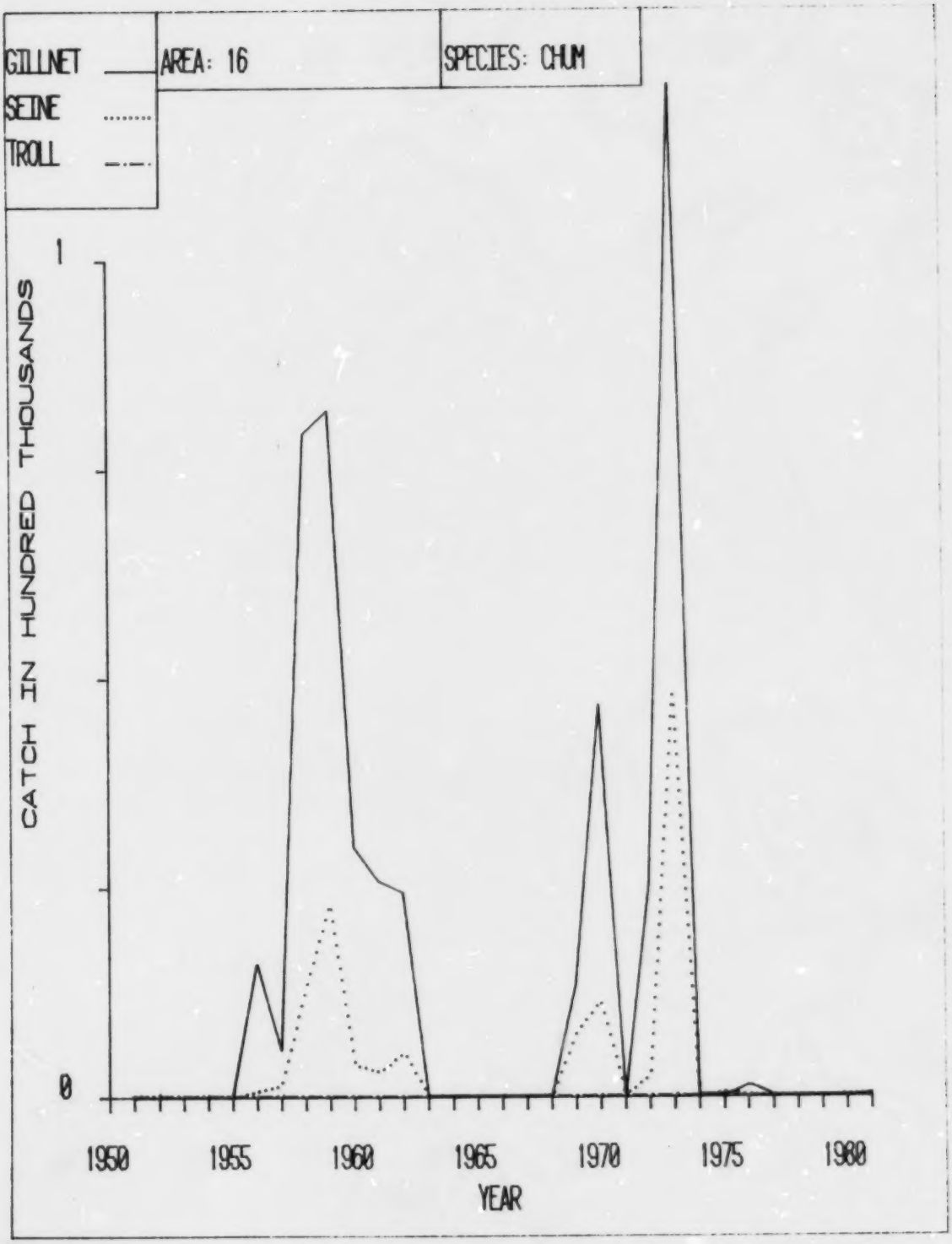

Fig. A16. Catch of chum salmon by gear in Statistical Area 16, 1951-1981.

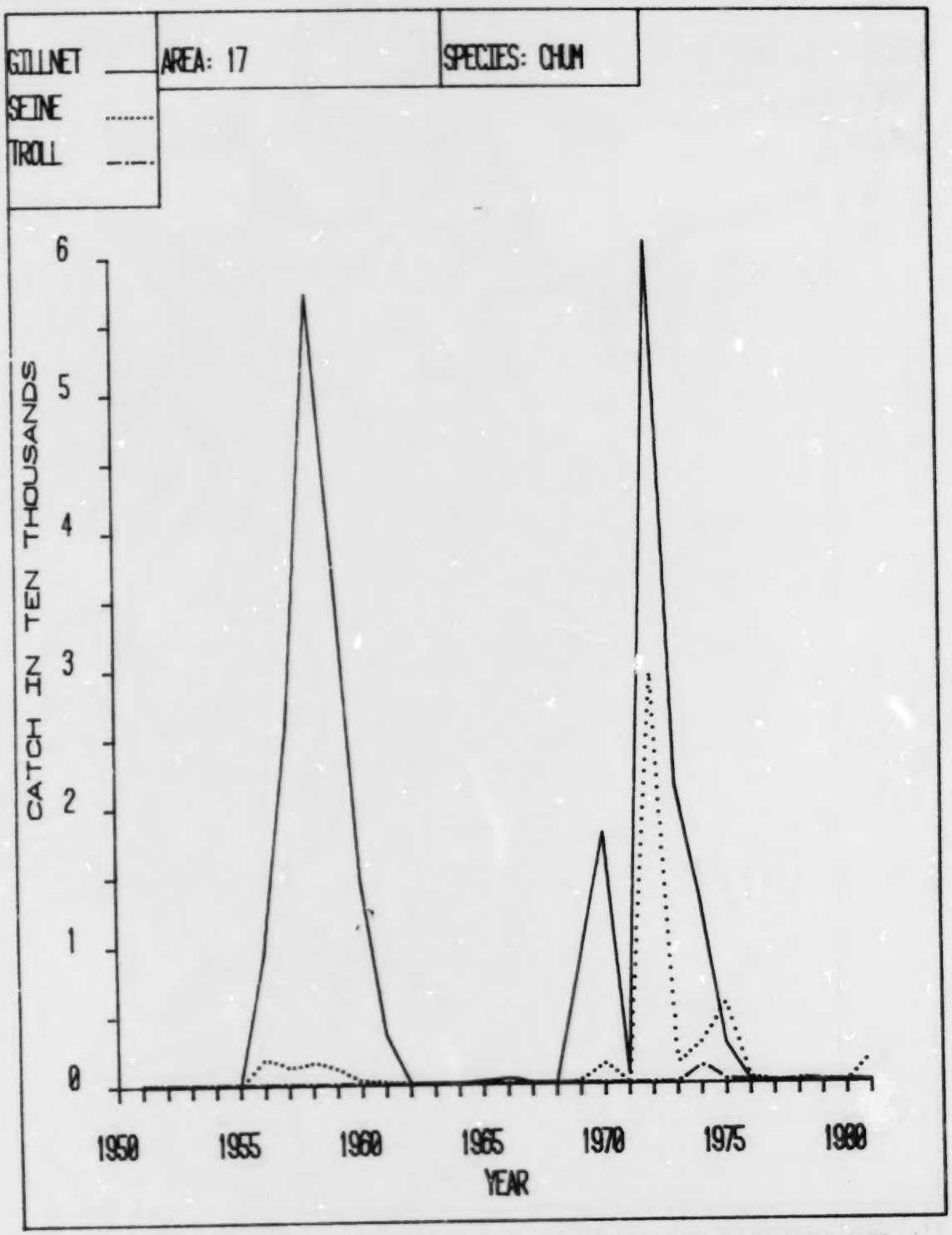

Fig. A17. Catch of chum salmon by gear in Statistical Area 17, 1951-1981

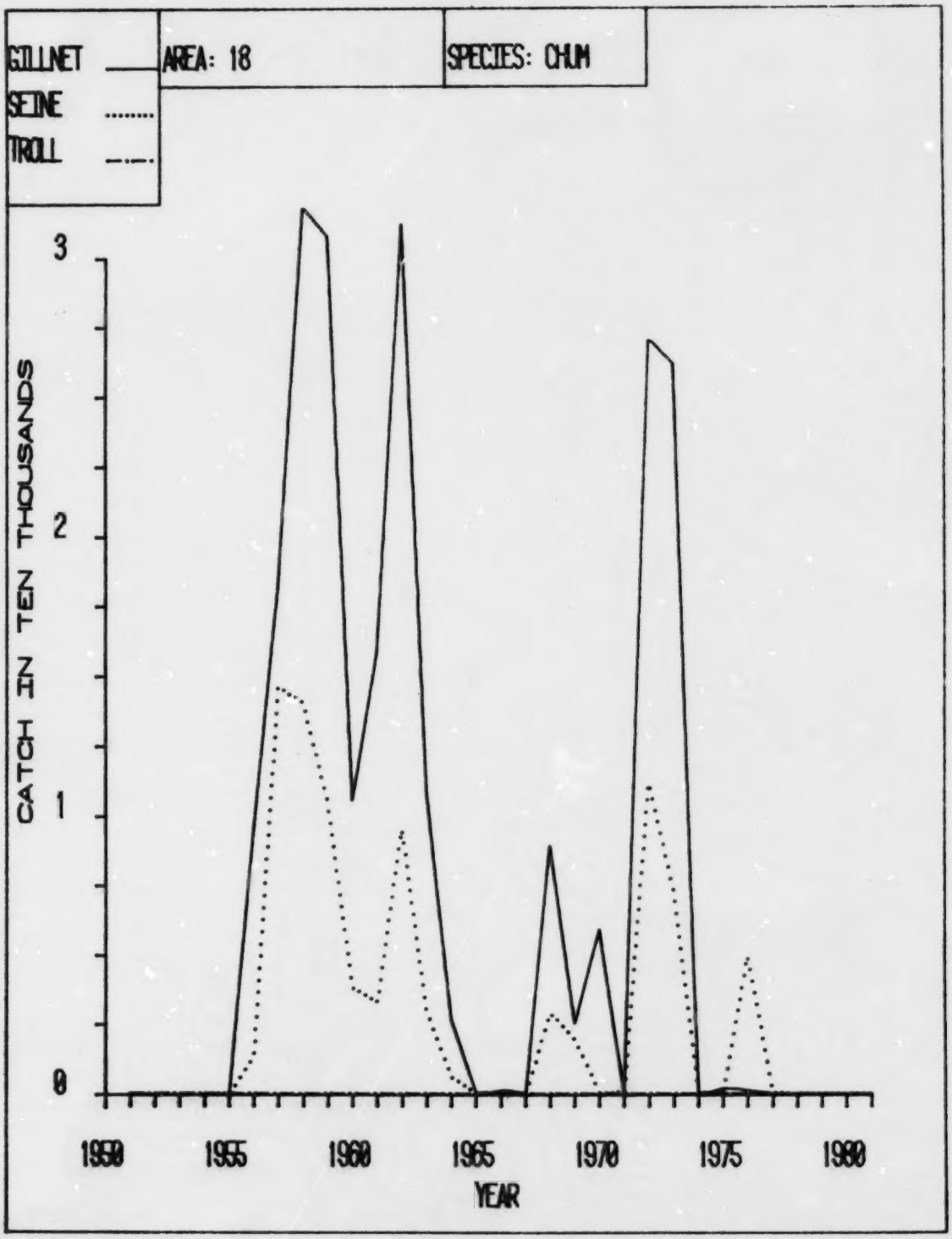

Fig. A18. Catch of chum salmon by gear in Statistical Area 18, 1951-1981.

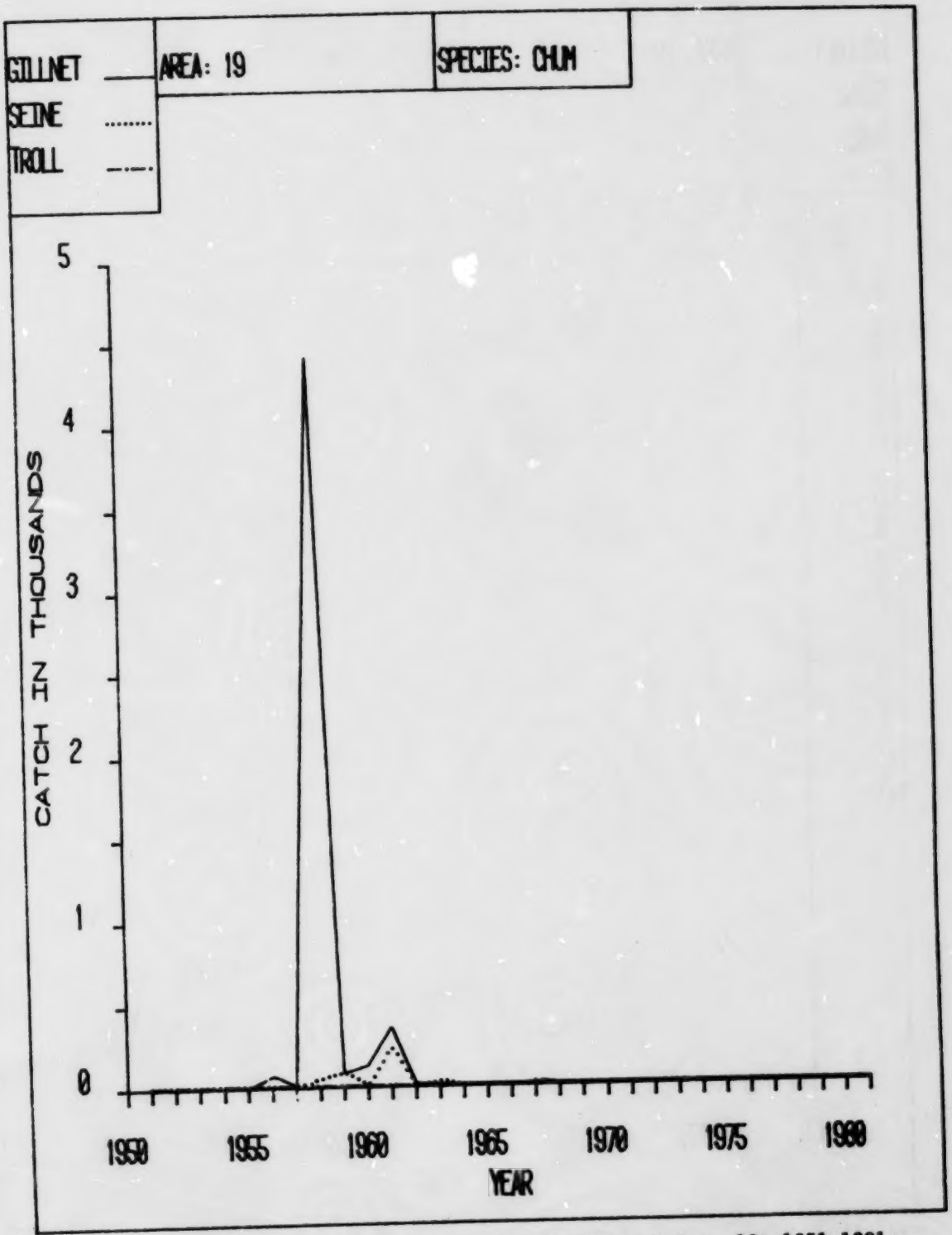

Fig. A19. Catch of chum salmon by gear in Statistical Area 19, 1951-1981.

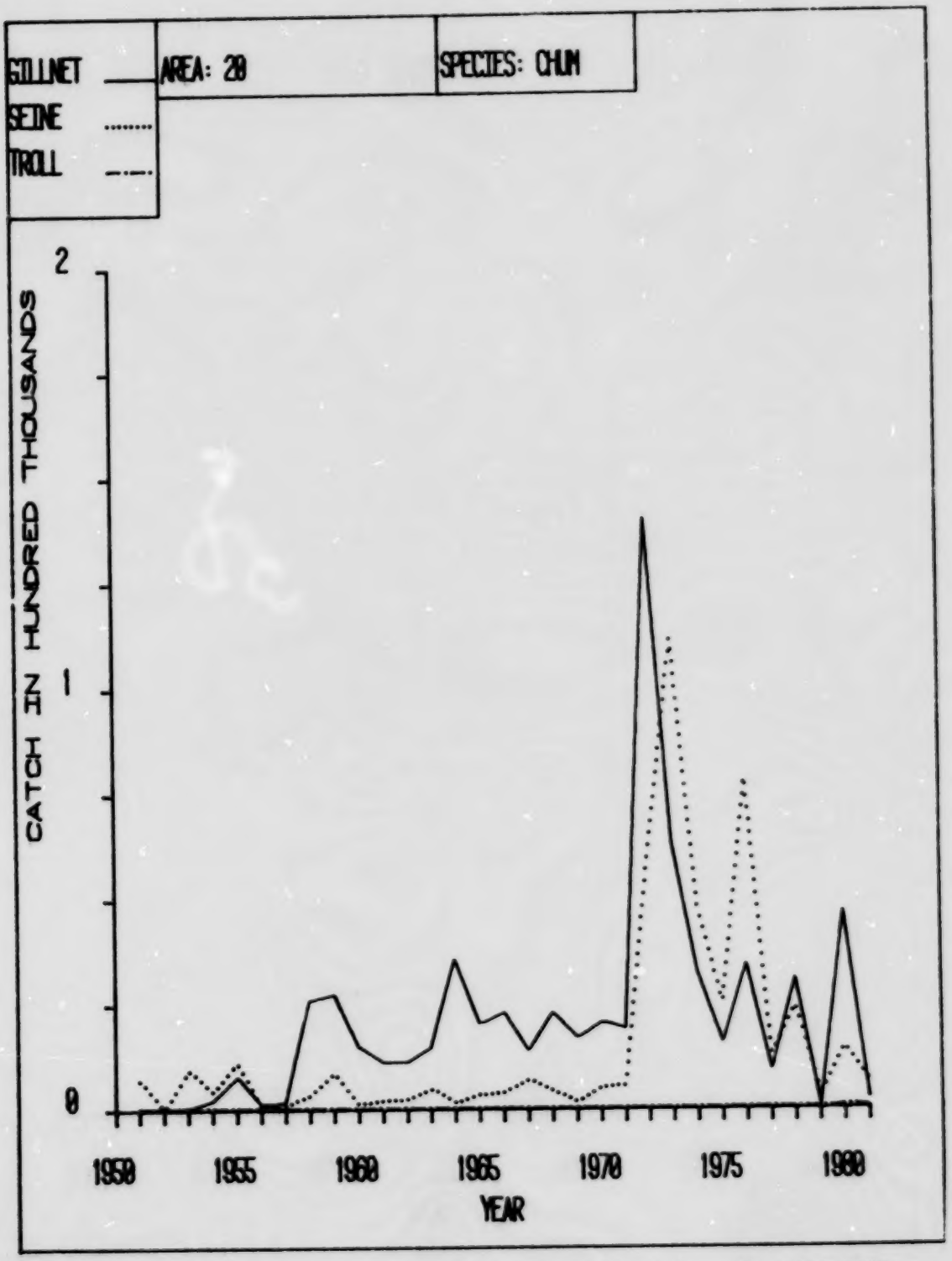

Fig. A20. Catch of chum salmon by gear in Statistical Area 20, 1951-1981.

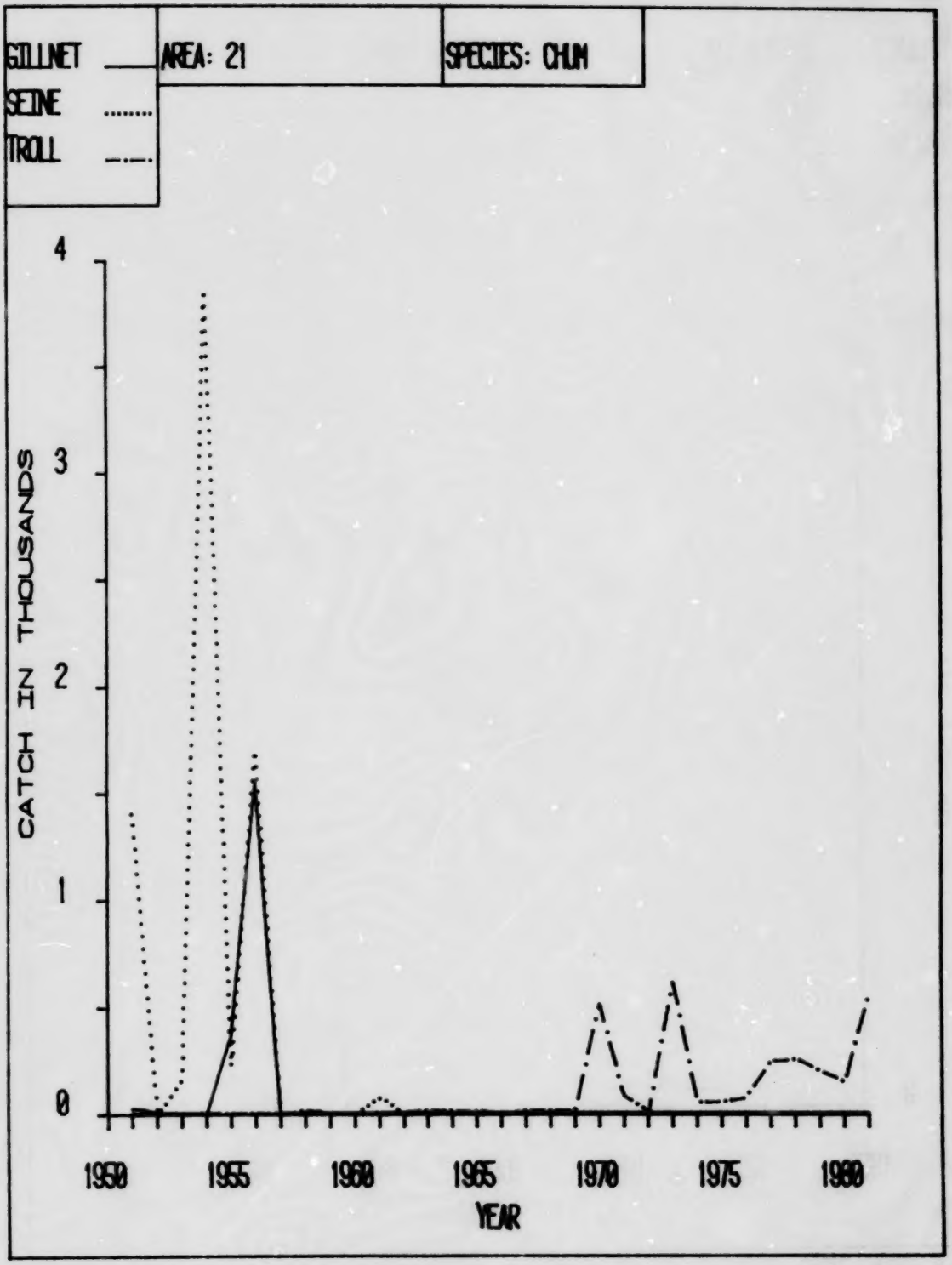

Fig. A21. Catch of chum salmon by gear in Statistical Area 21, 1951-1981.

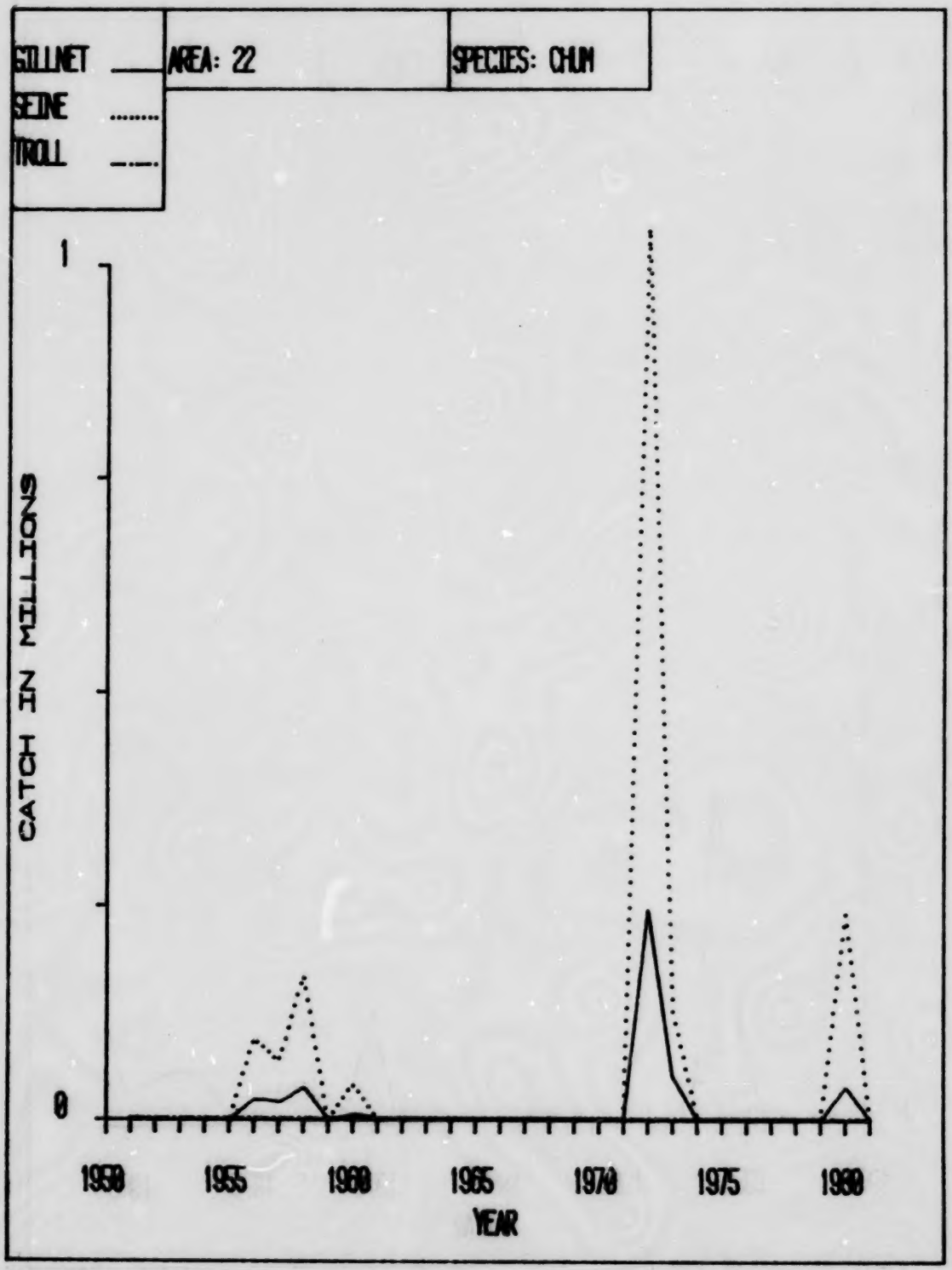

Fig. A22. Catch of chum salmon by gear in Statistical Area 22, 1951-1981.

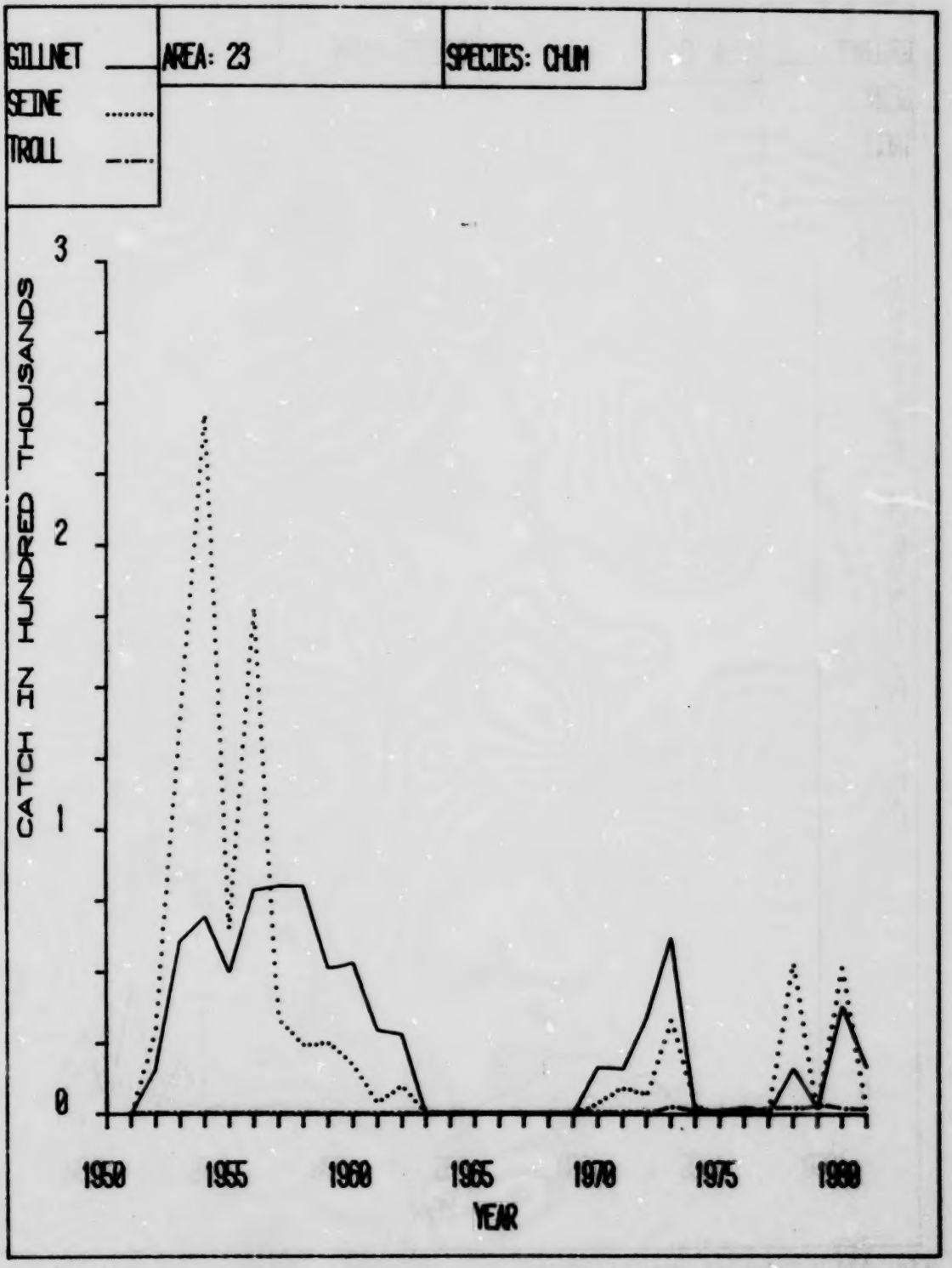

Fig. A23. Catch of chum salmon by gear in Statistical Area 23, 1951-1981.

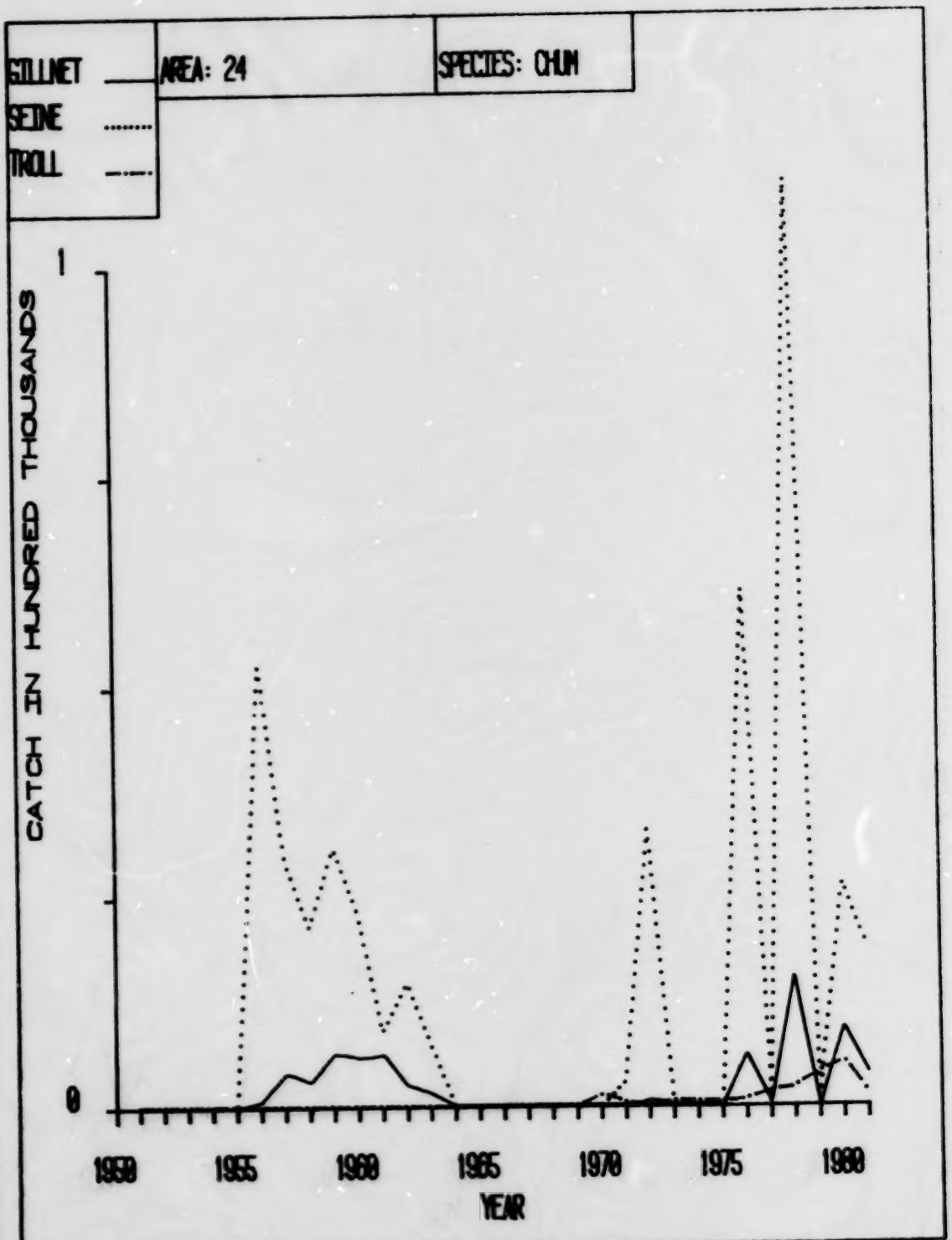

Fig. A24. Catch of chum salmon by gear in Statistical Area 24, 1951-1981.

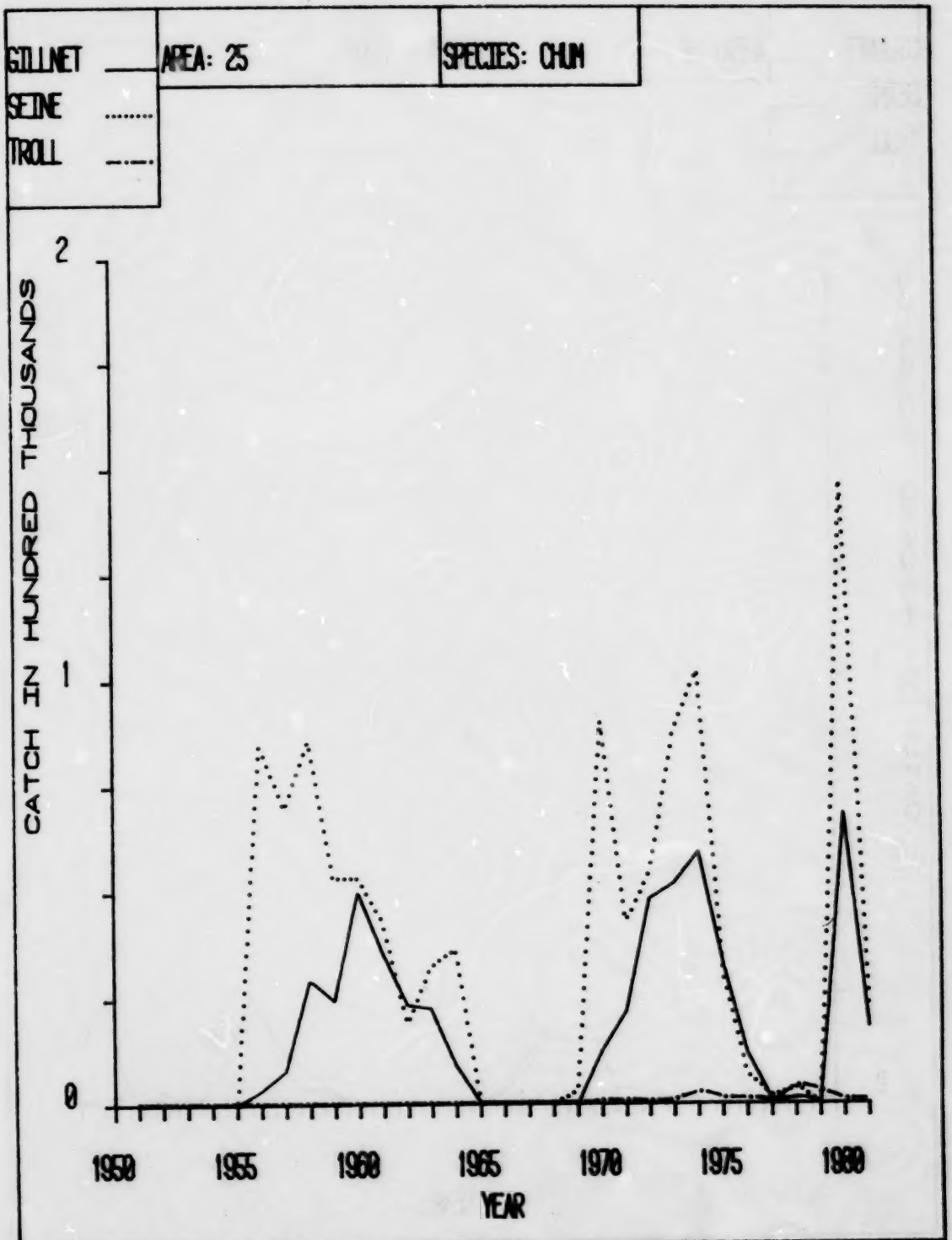

Fig. A25. Catch of chum salmon by gear in Statistical Area 25, 1951-1981.

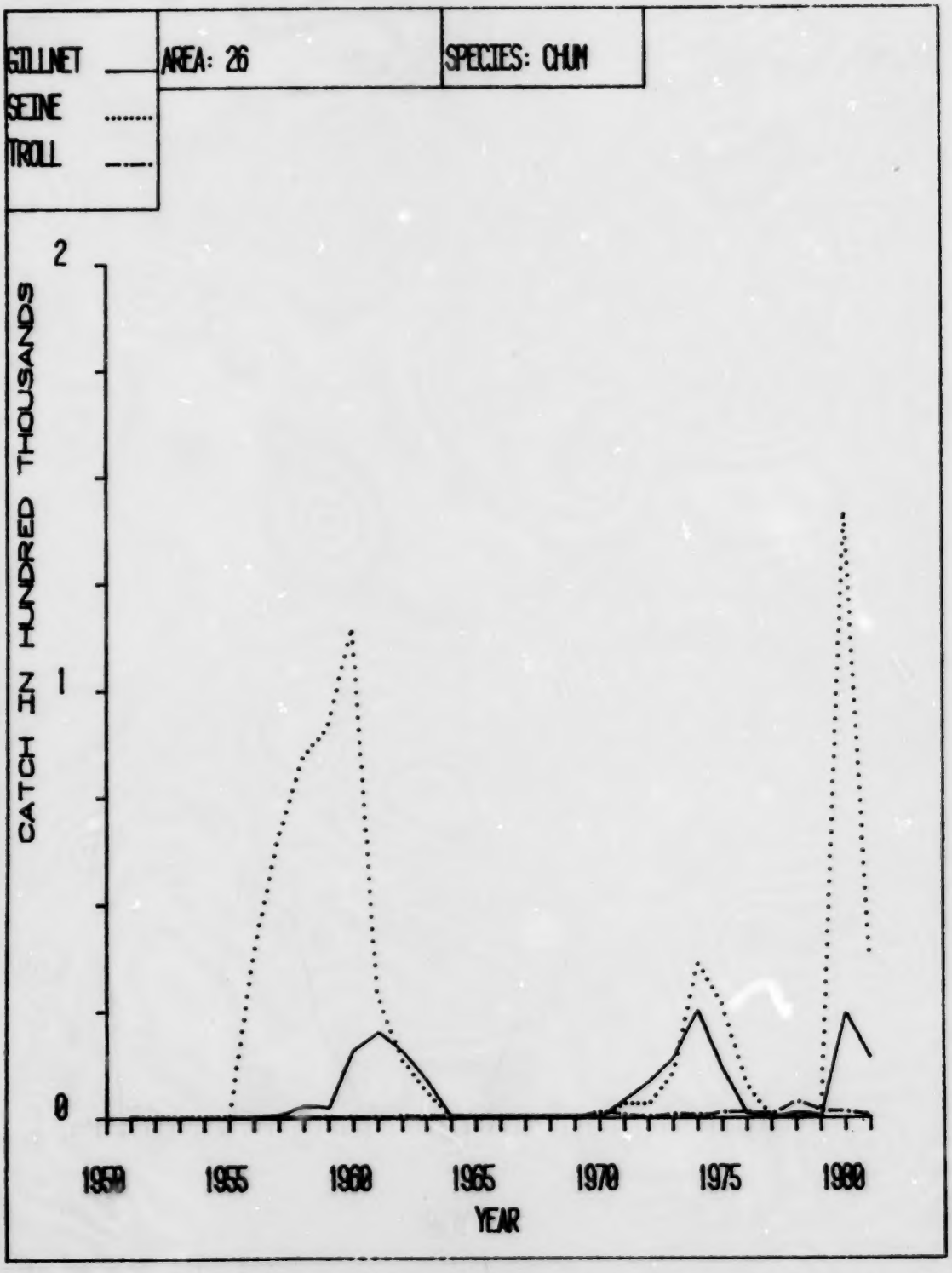

Fig. A26. Catch of chum salmon by gear in Statistical Area 26, 1951-1981.

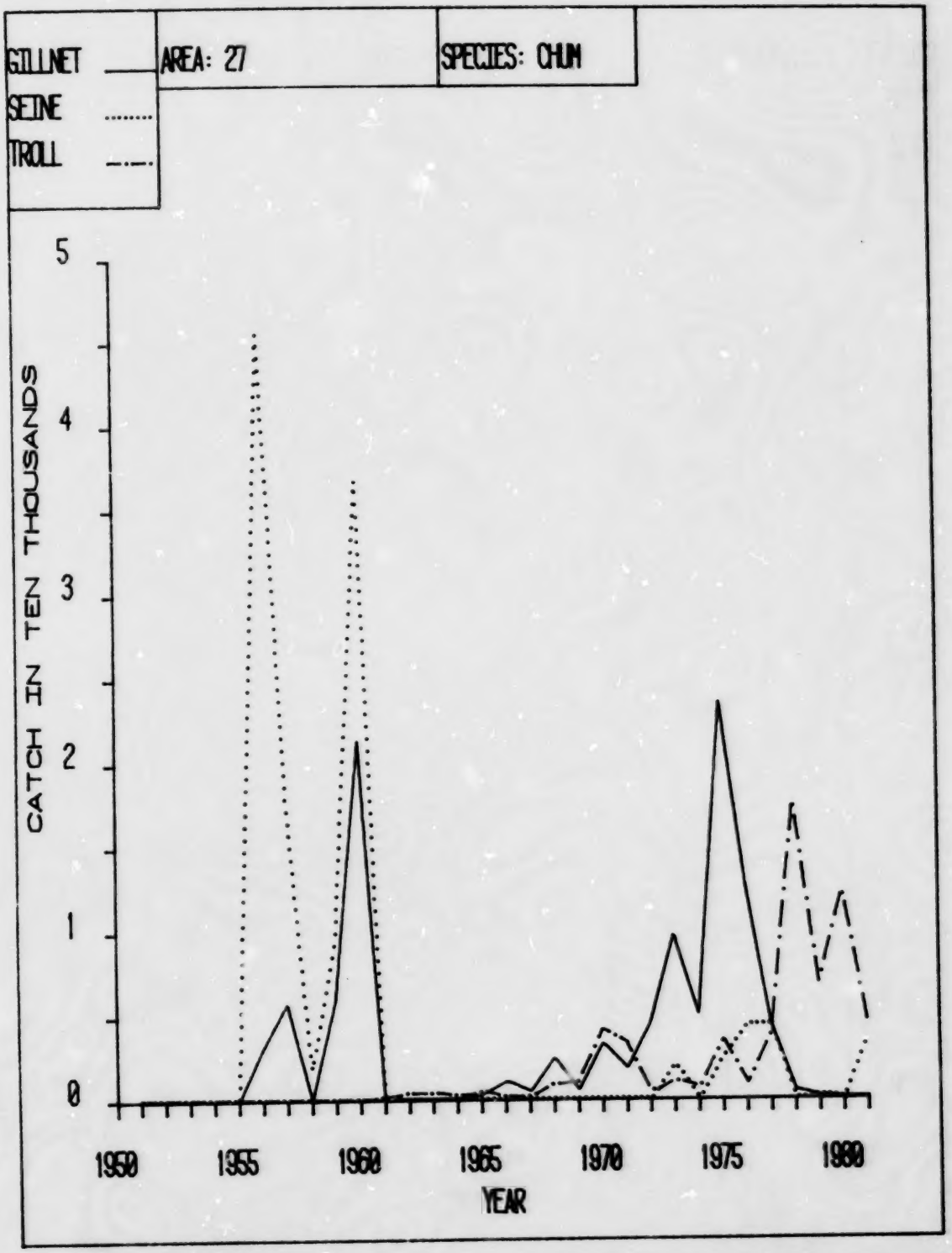

Fig. A27. Catch of chum salmon by gear in Statistical Area 27, 1951-1981.

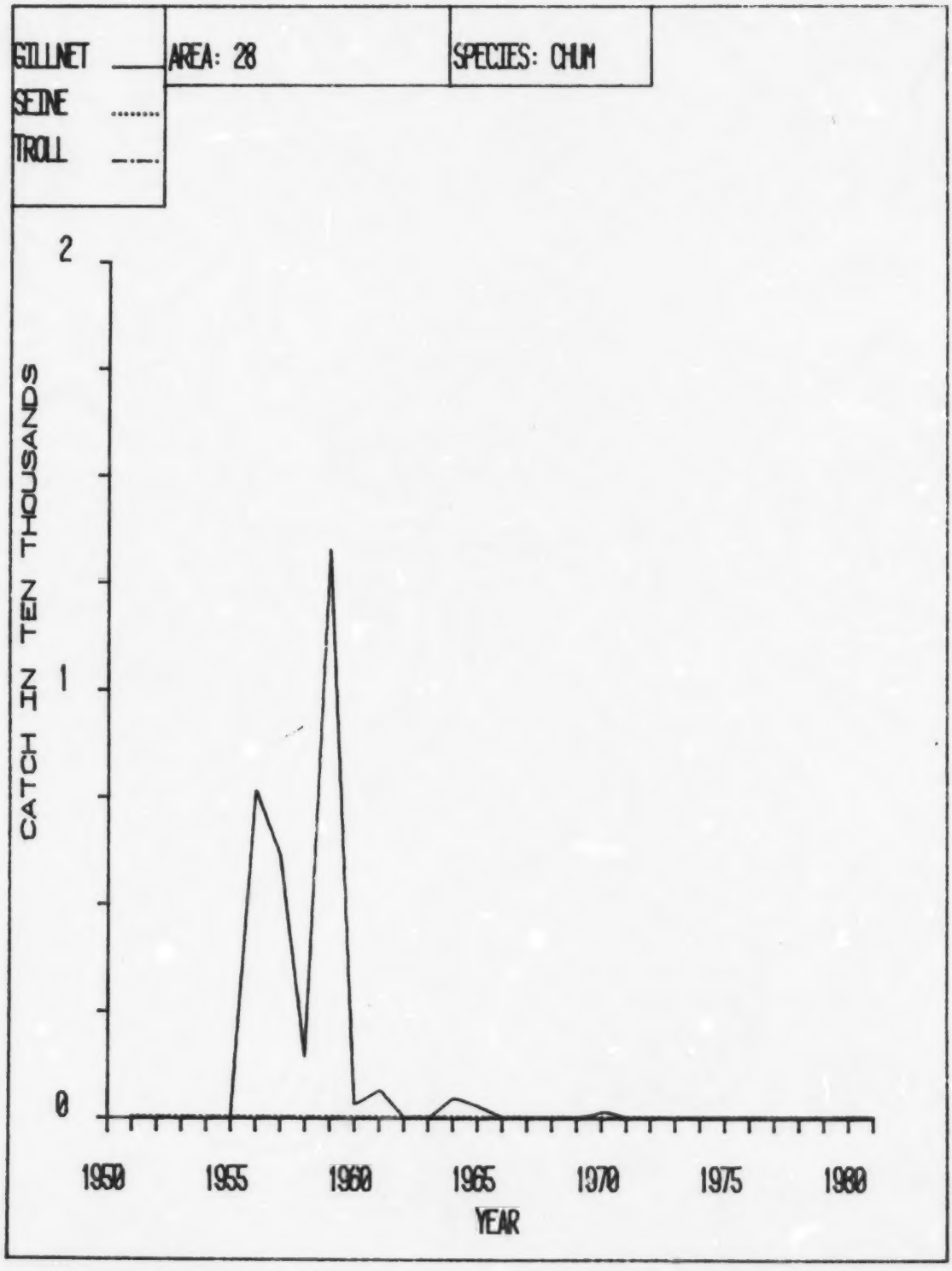

Fig. A28. Catch of chum salmon by gear in Statistical Area 28, 1951-1981.

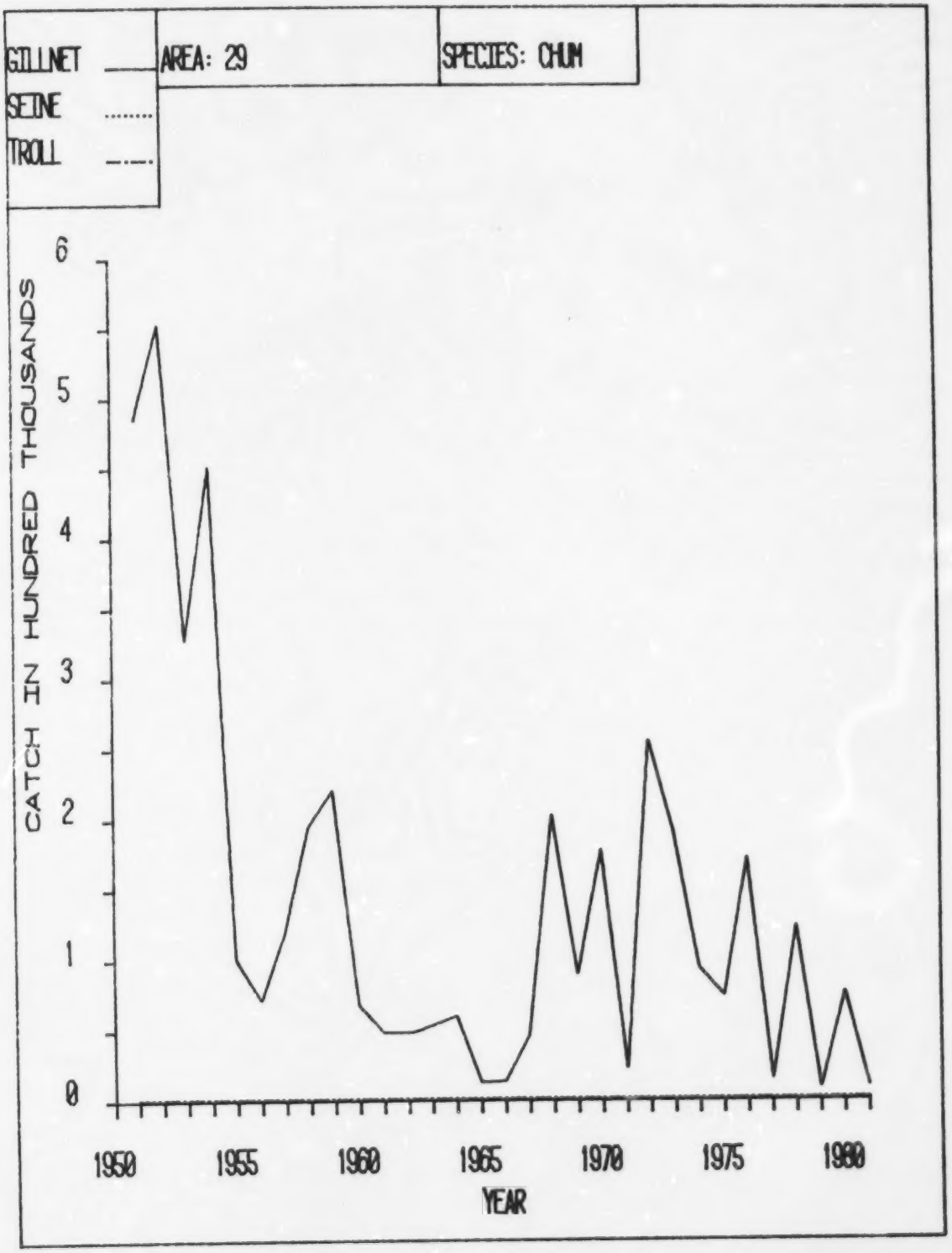

Fig. A29. Catch of chum salmon by gear in Statistical Area 29, 1951-1981.

APPENDIX B

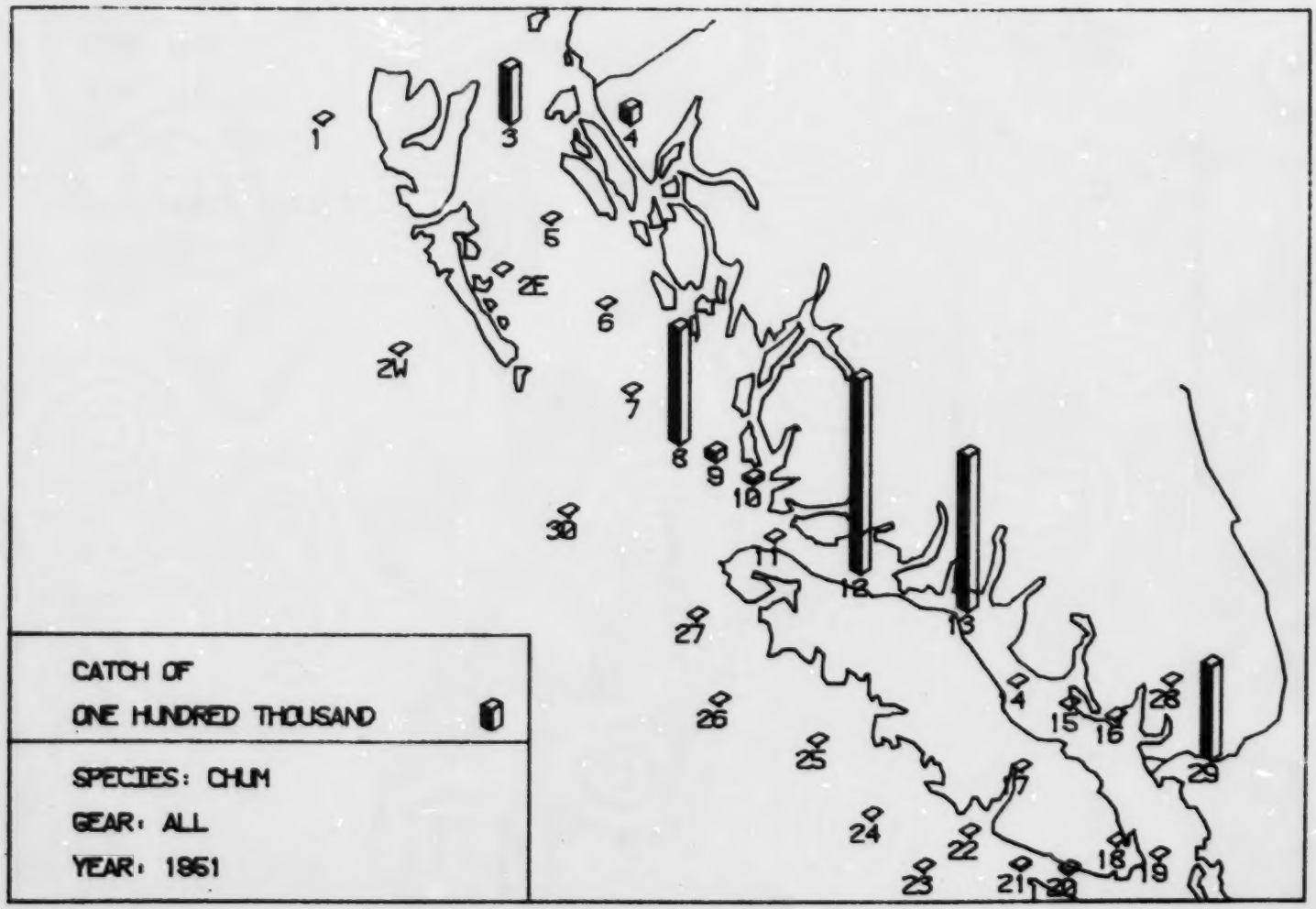

Fig. B1. Catch of chum salmon by Statistical Area in 1951.

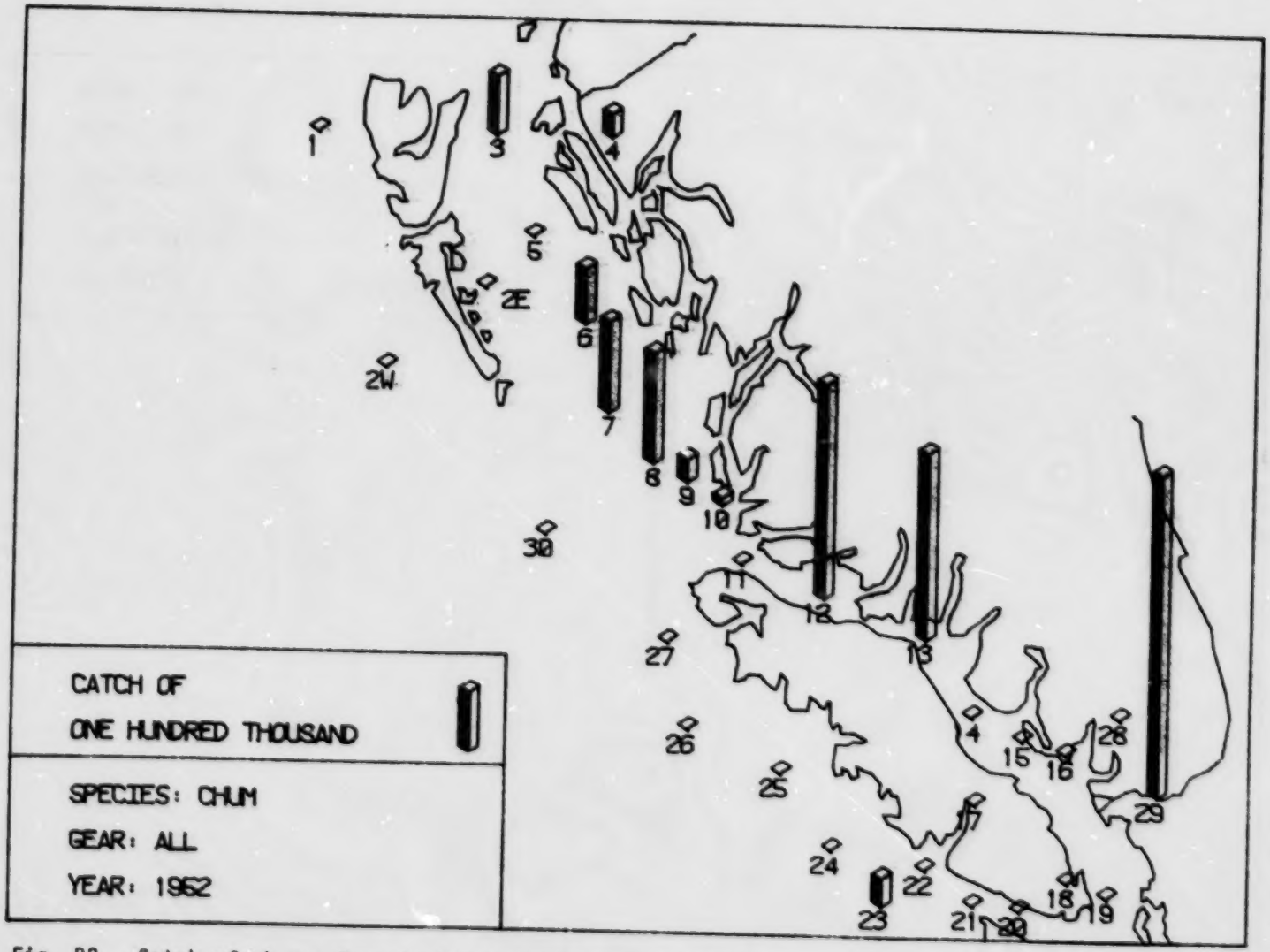

Fig. B2. Catch of chum salmon by Statistical Area in 1952.

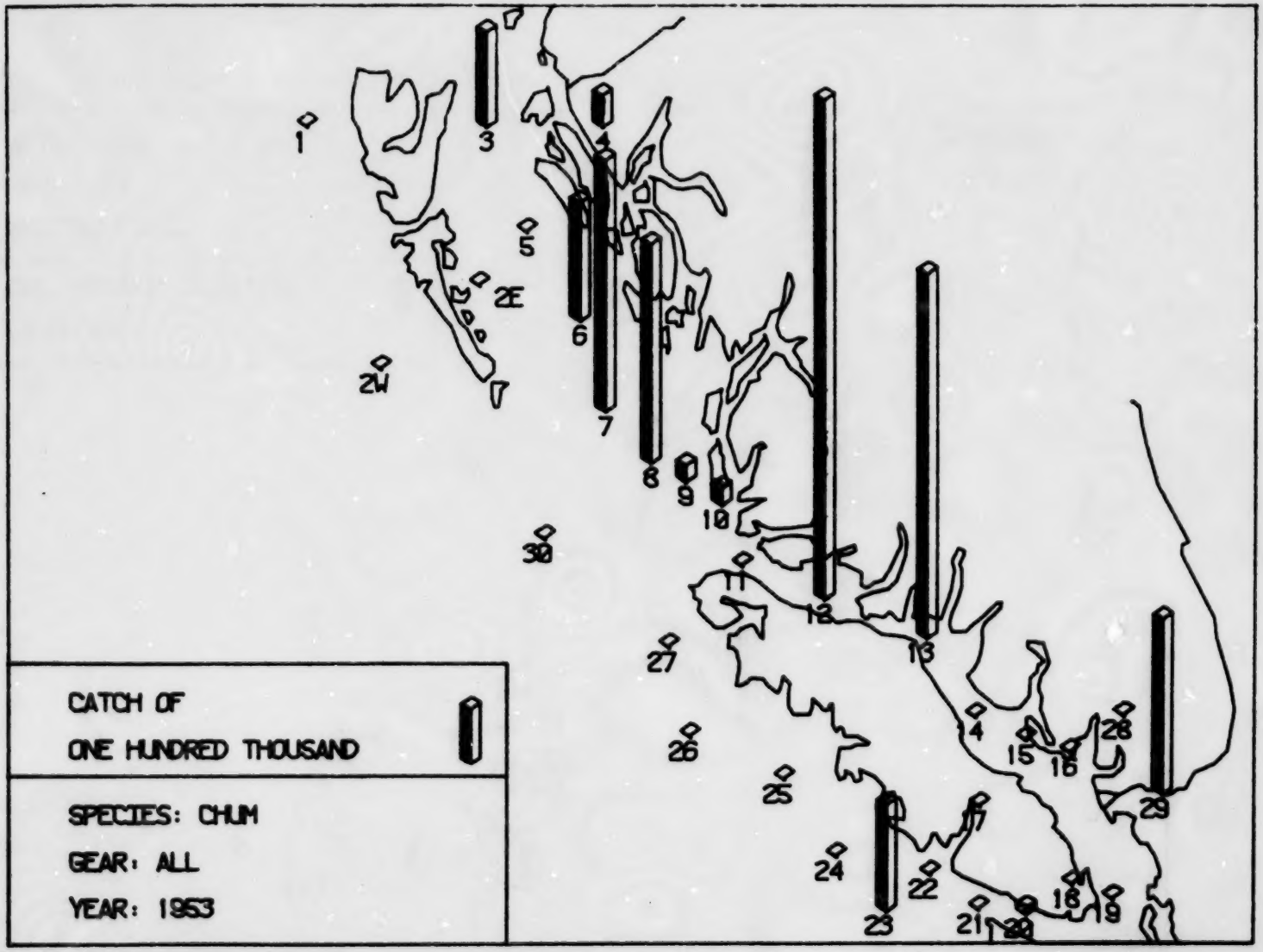

Fig. B3. Catch of chum salmon by Statistical Area in 1953.

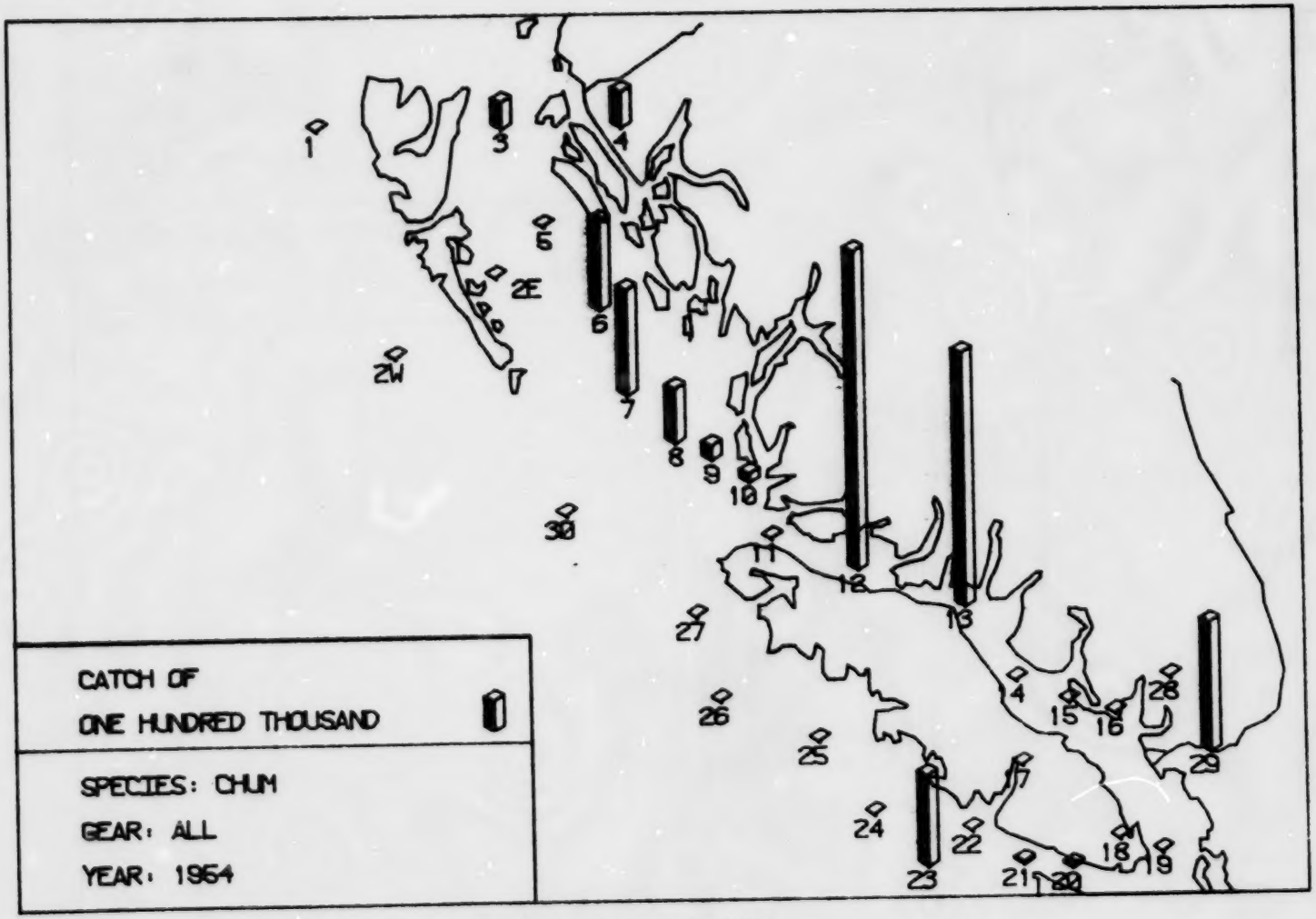

Fig. B4. Catch of chum salmon by Statistical Area in 1954.

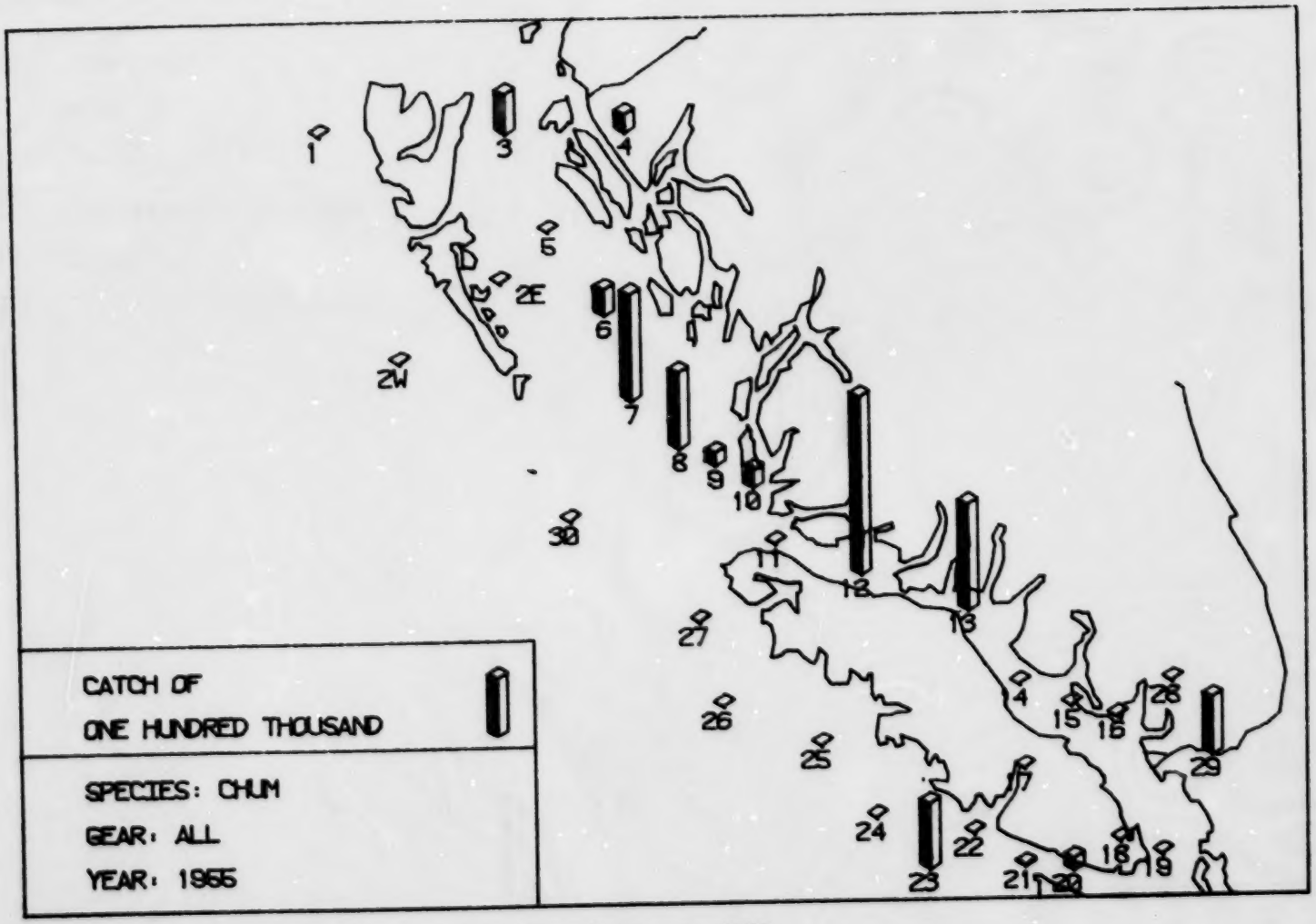

Fig. B5. Catch of chum salmon by Statistical Area in 1955.

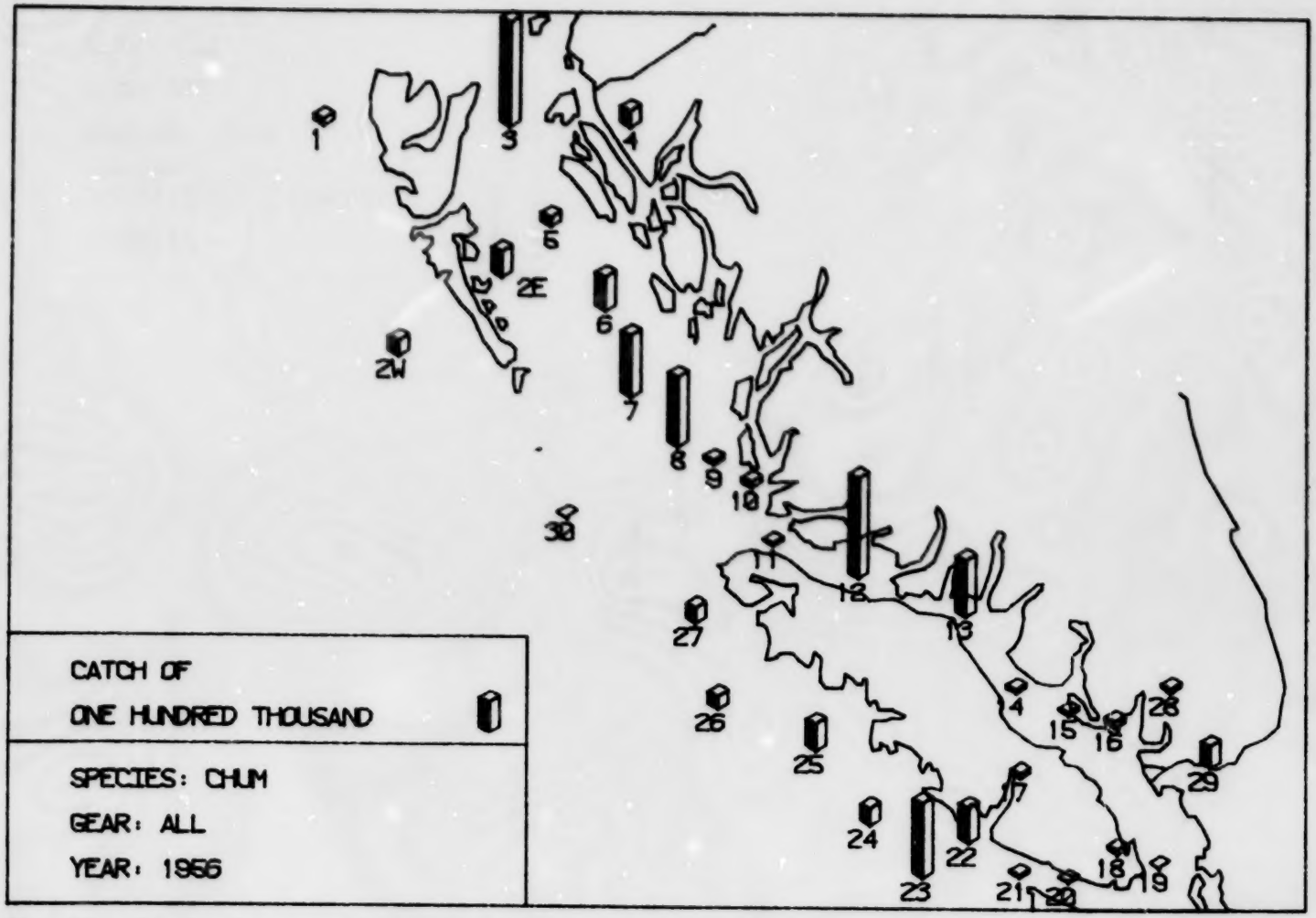

Fig. B6. Catch of chum salmon by Statistical Area in 1956.

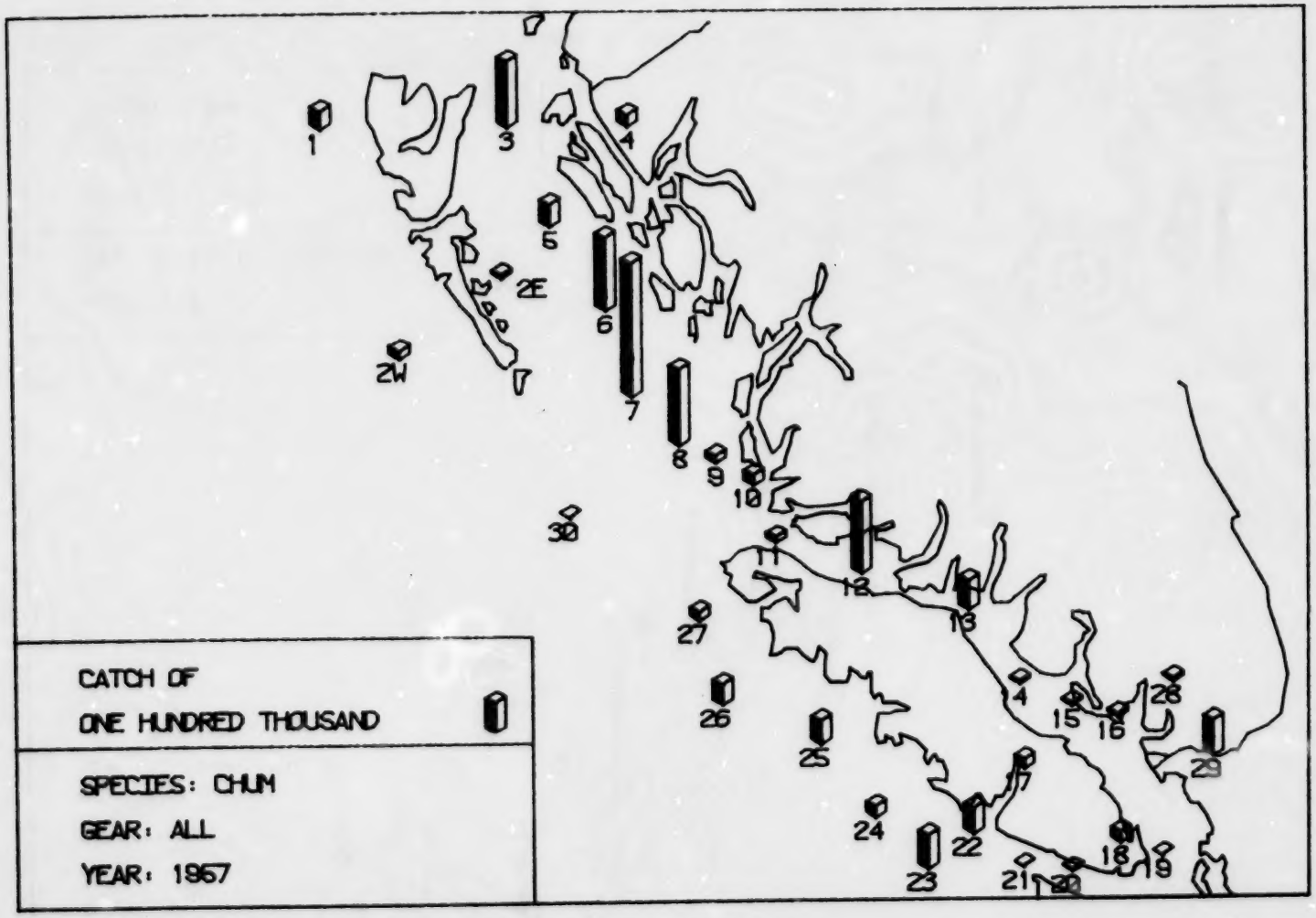

Fig. B7. Catch of chum salmon by Statistical Area in 1957.

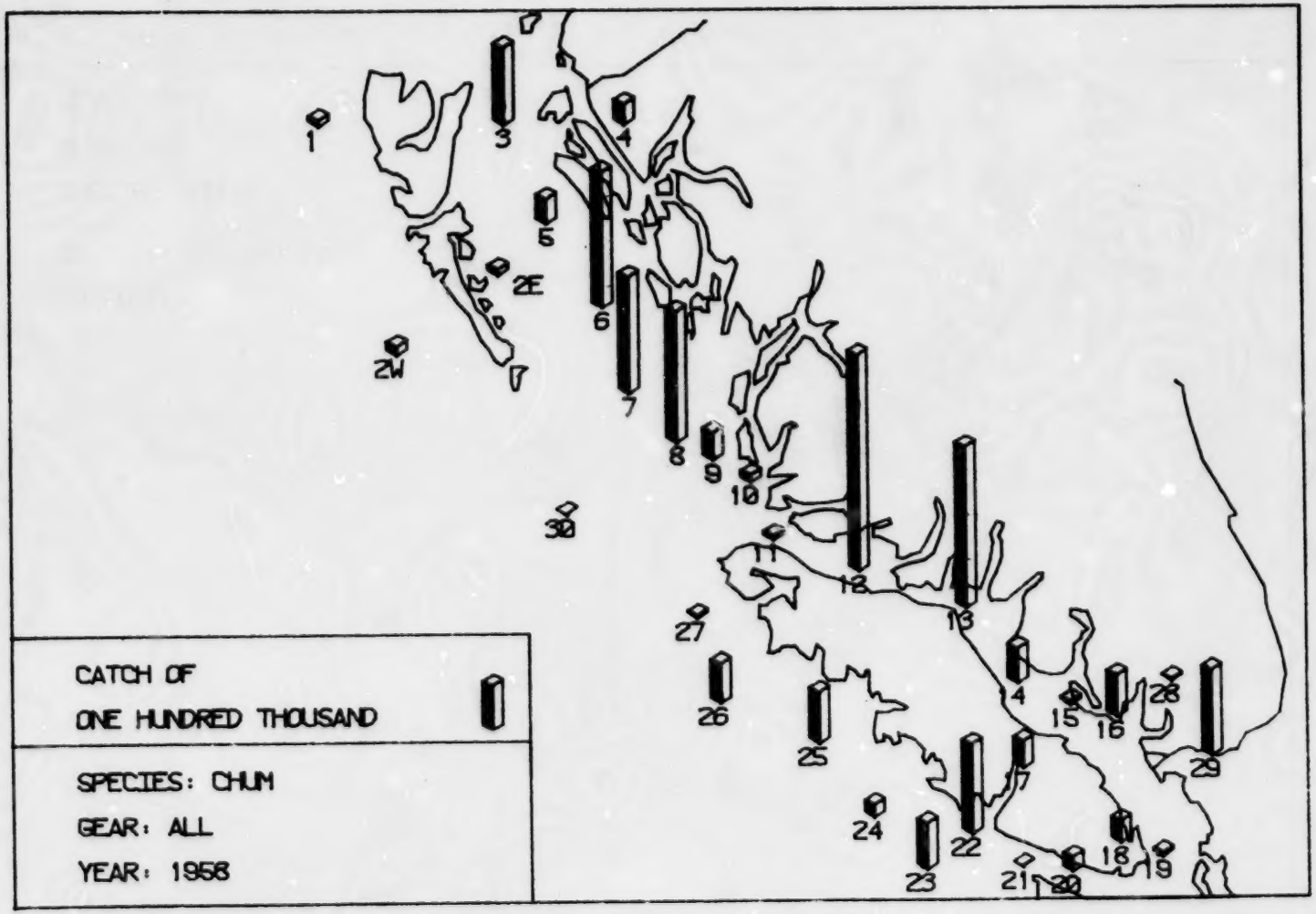

Fig. B8. Catch of chum salmon by Statistical Area in 1958.

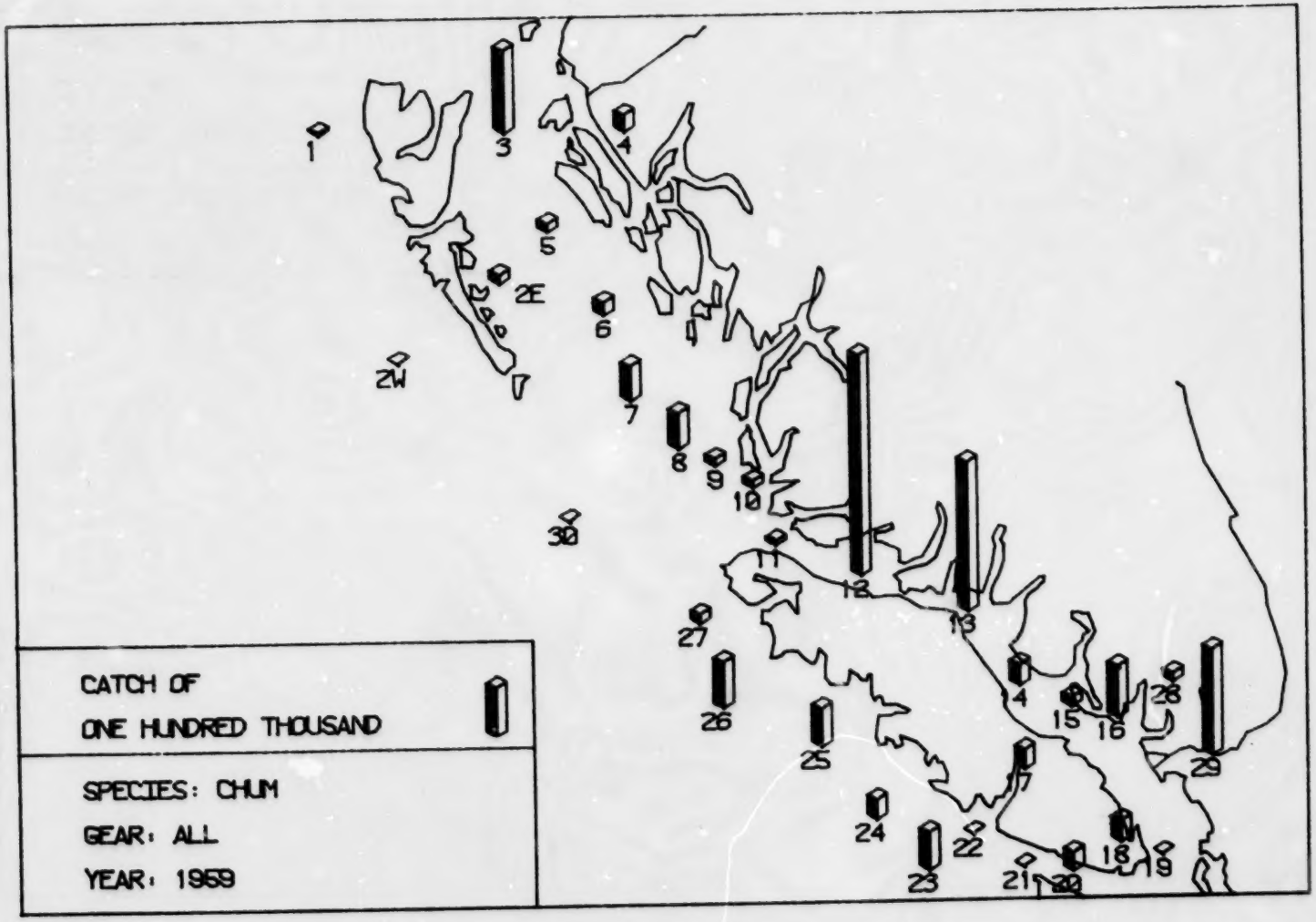

Fig. B9. Catch of chum salmon by Statistical Area in 1959.

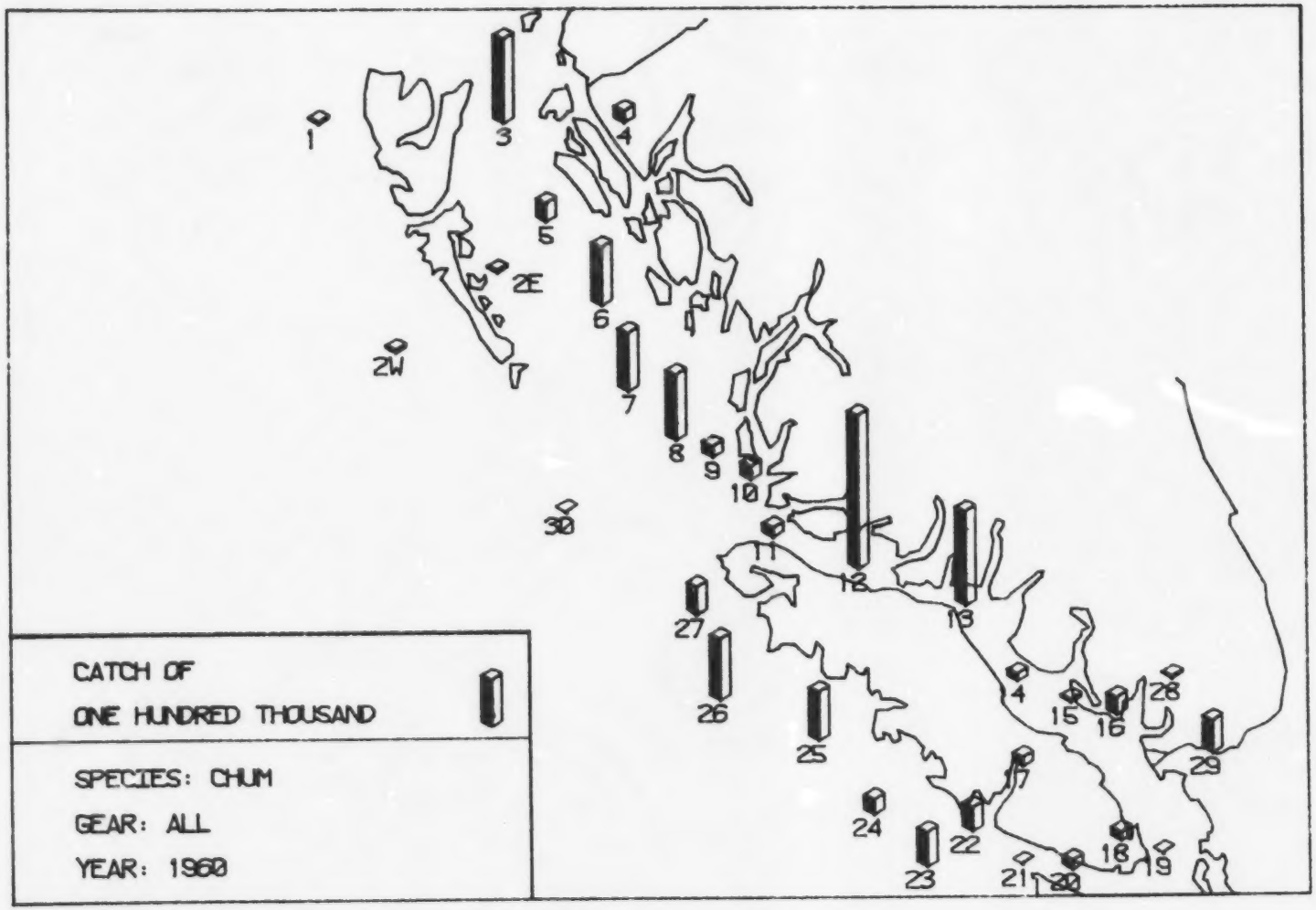

Fig. B10. Catch of chum salmon by Statistical Area in 1960.

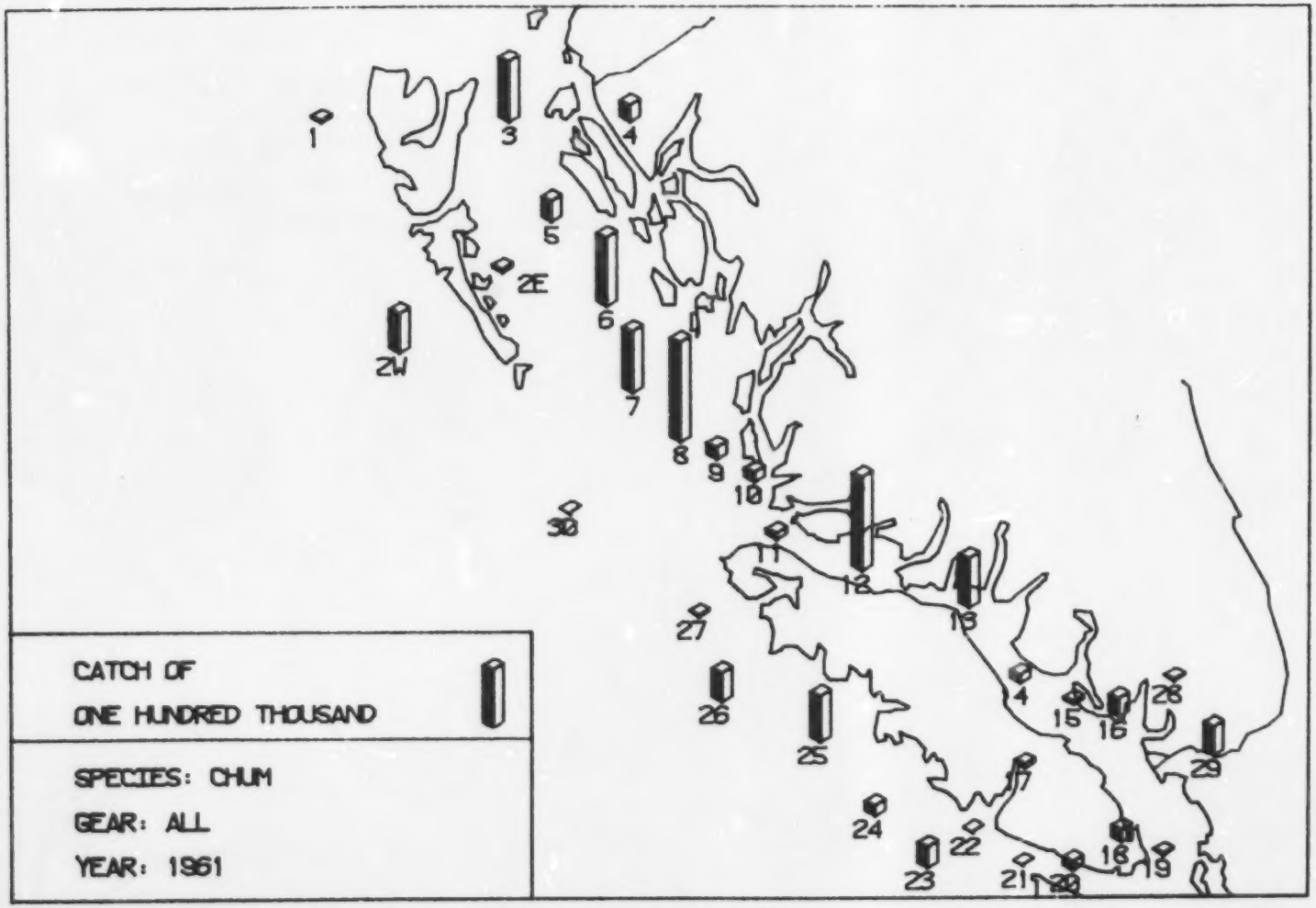

Fig. B11. Catch of chum salmon by Statistical Area in 1961.

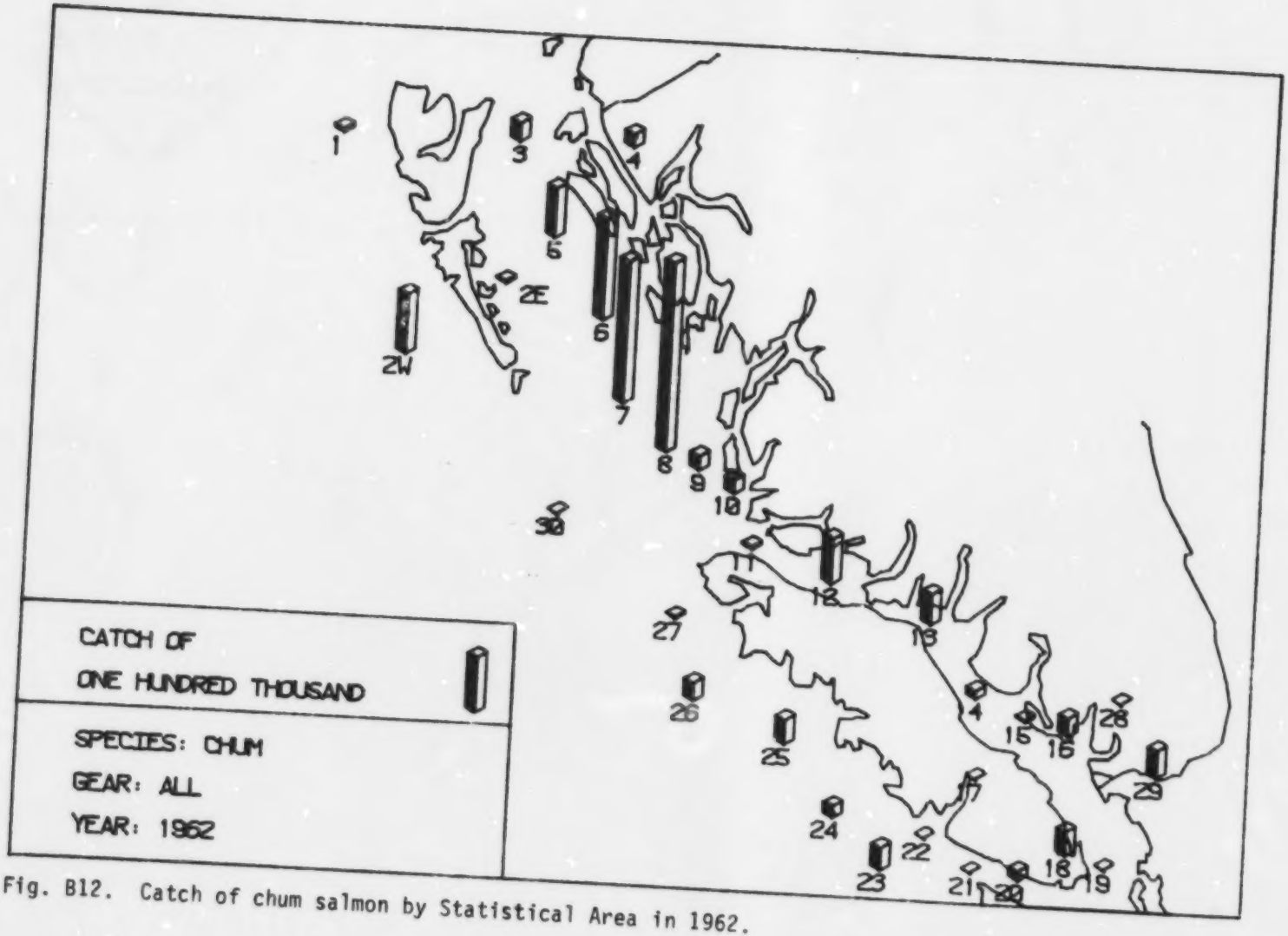

Fig. B12. Catch of chum salmon by Statistical Area in 1962.

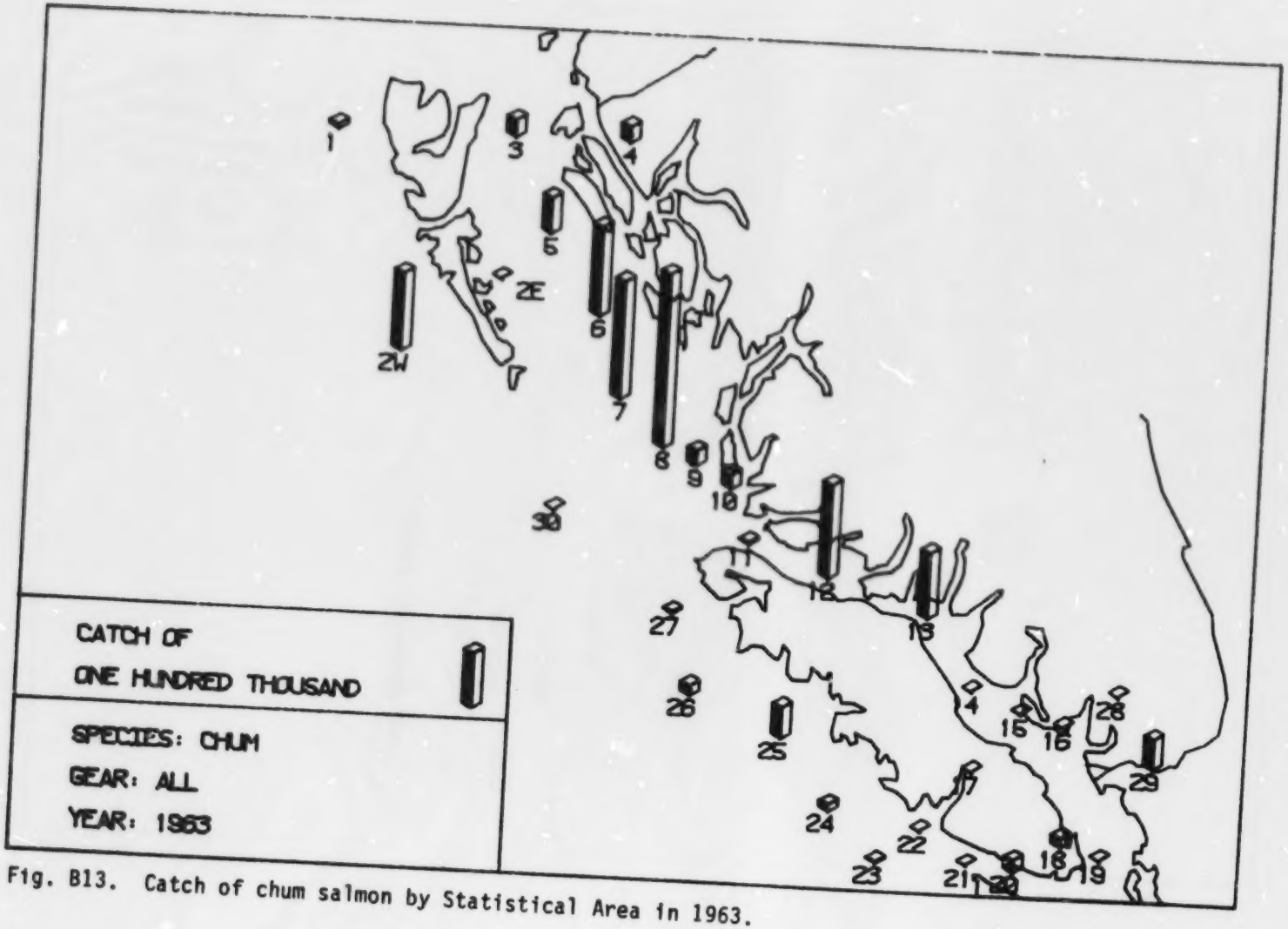

Fig. B13. Catch of chum salmon by Statistical Area in 1963.

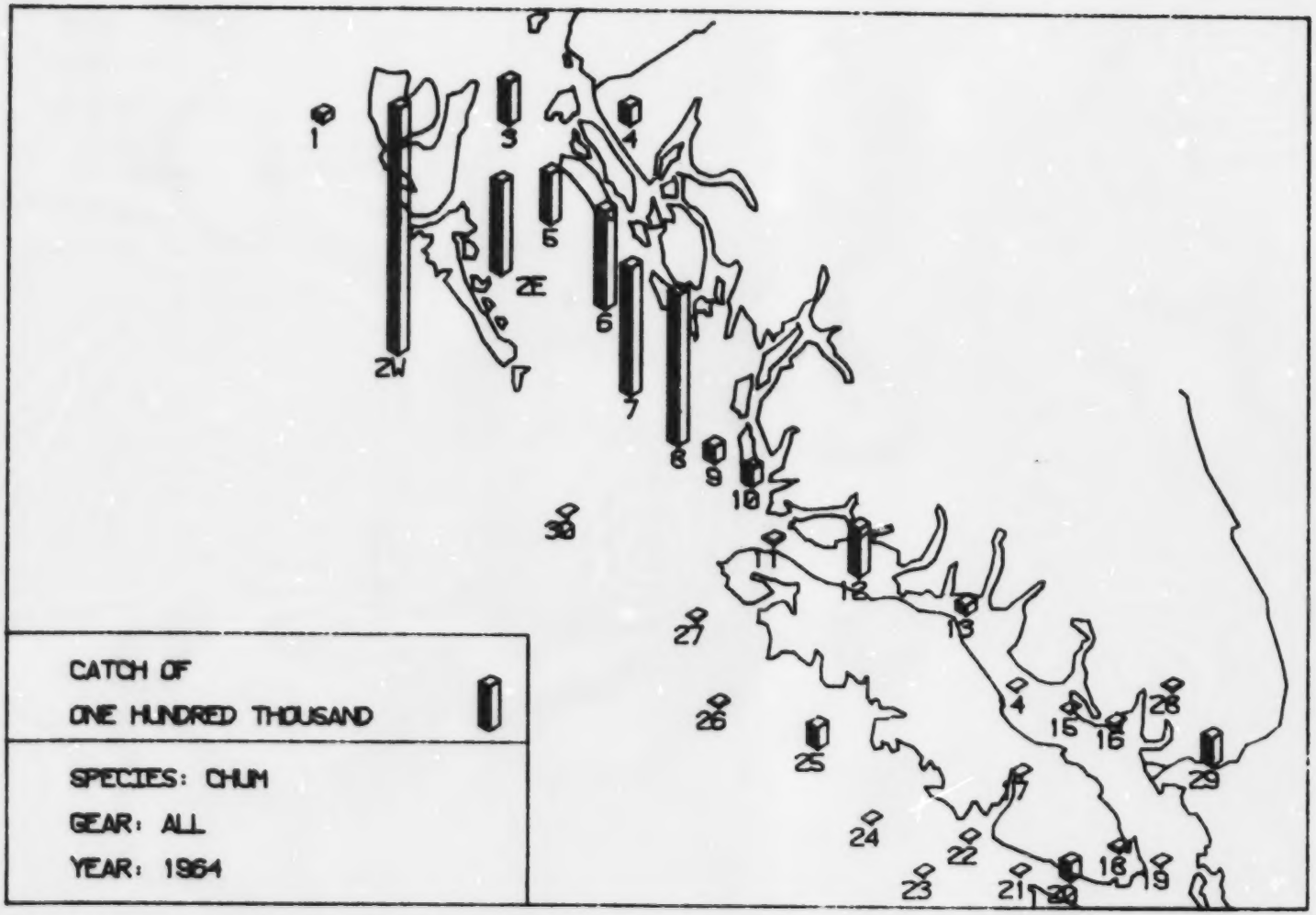

Fig. B14. Catch of chum salmon by Statistical Area in 1964.

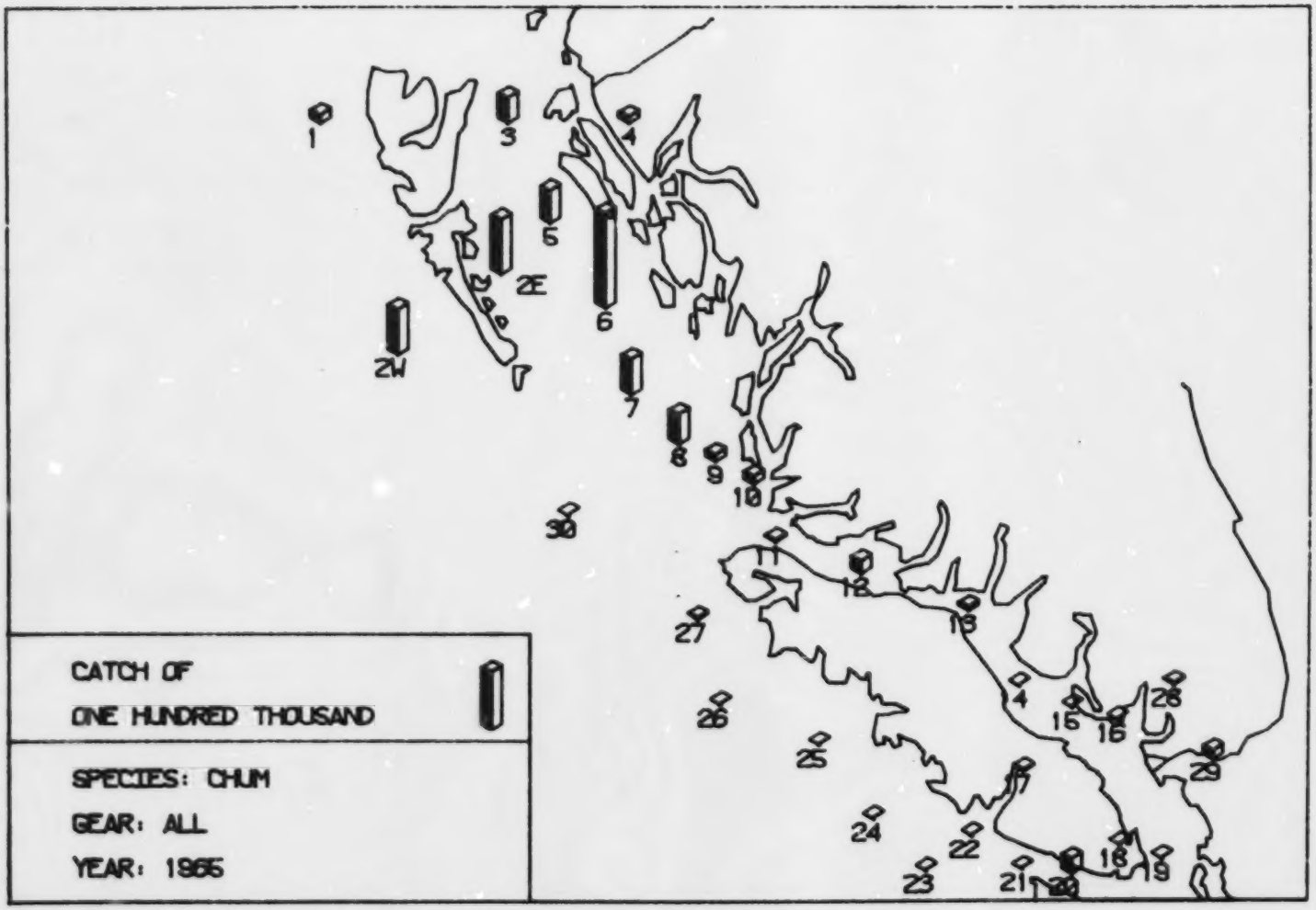

Fig. B15. Catch of chum salmon by Statistical Area in 1965.

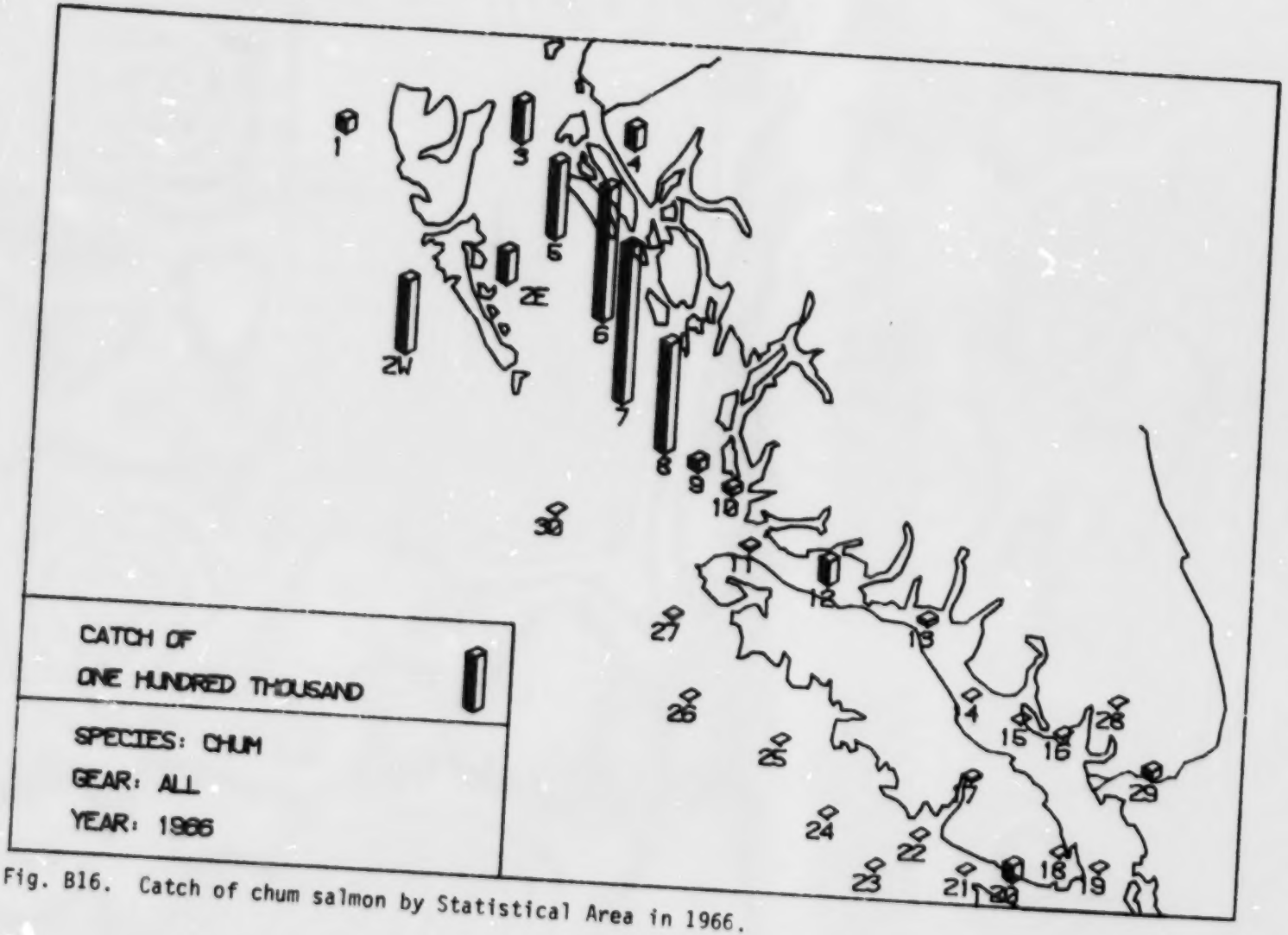

Fig. B16. Catch of chum salmon by Statistical Area in 1966.

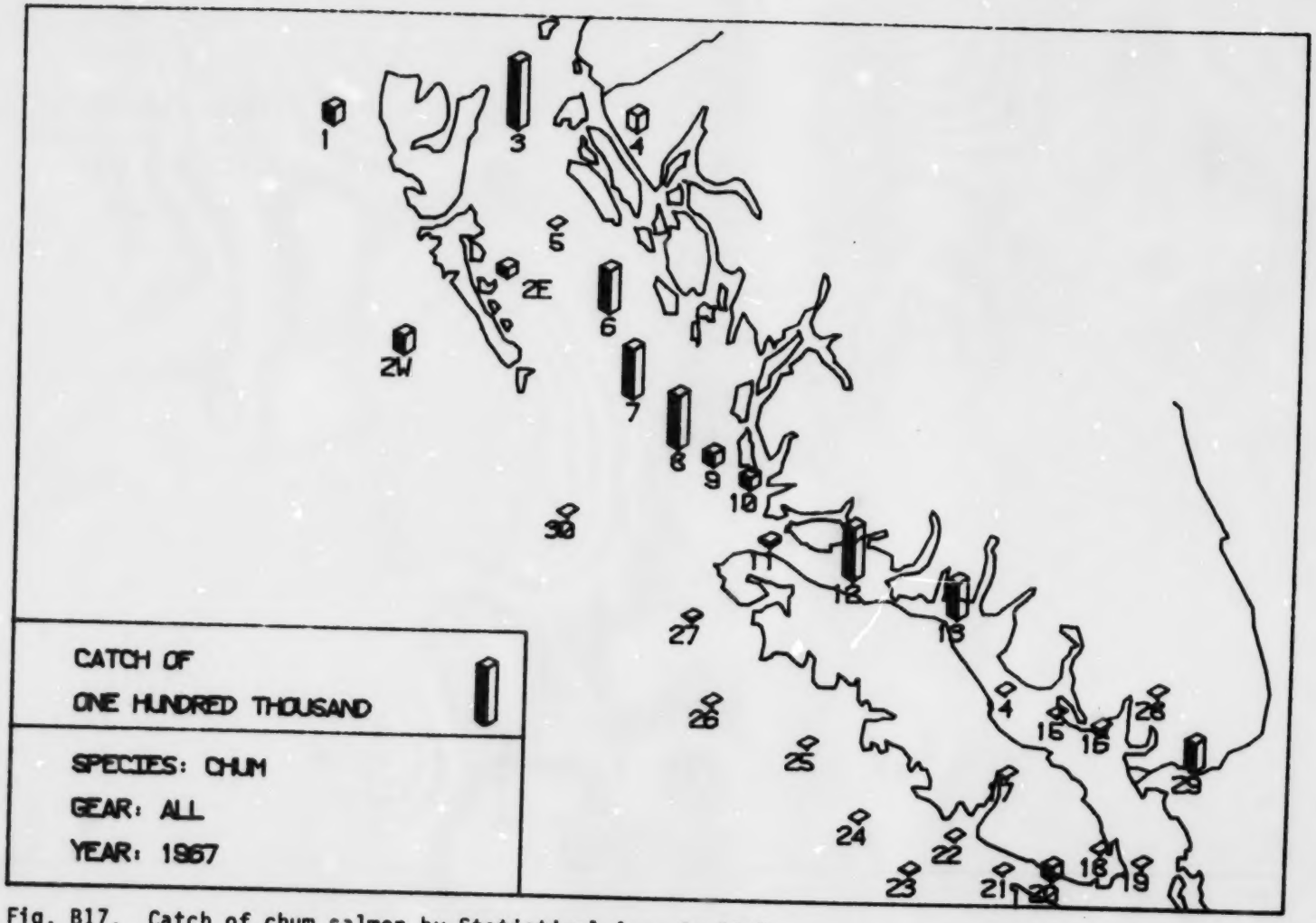

Fig. B17. Catch of chum salmon by Statistical Area in 1967.

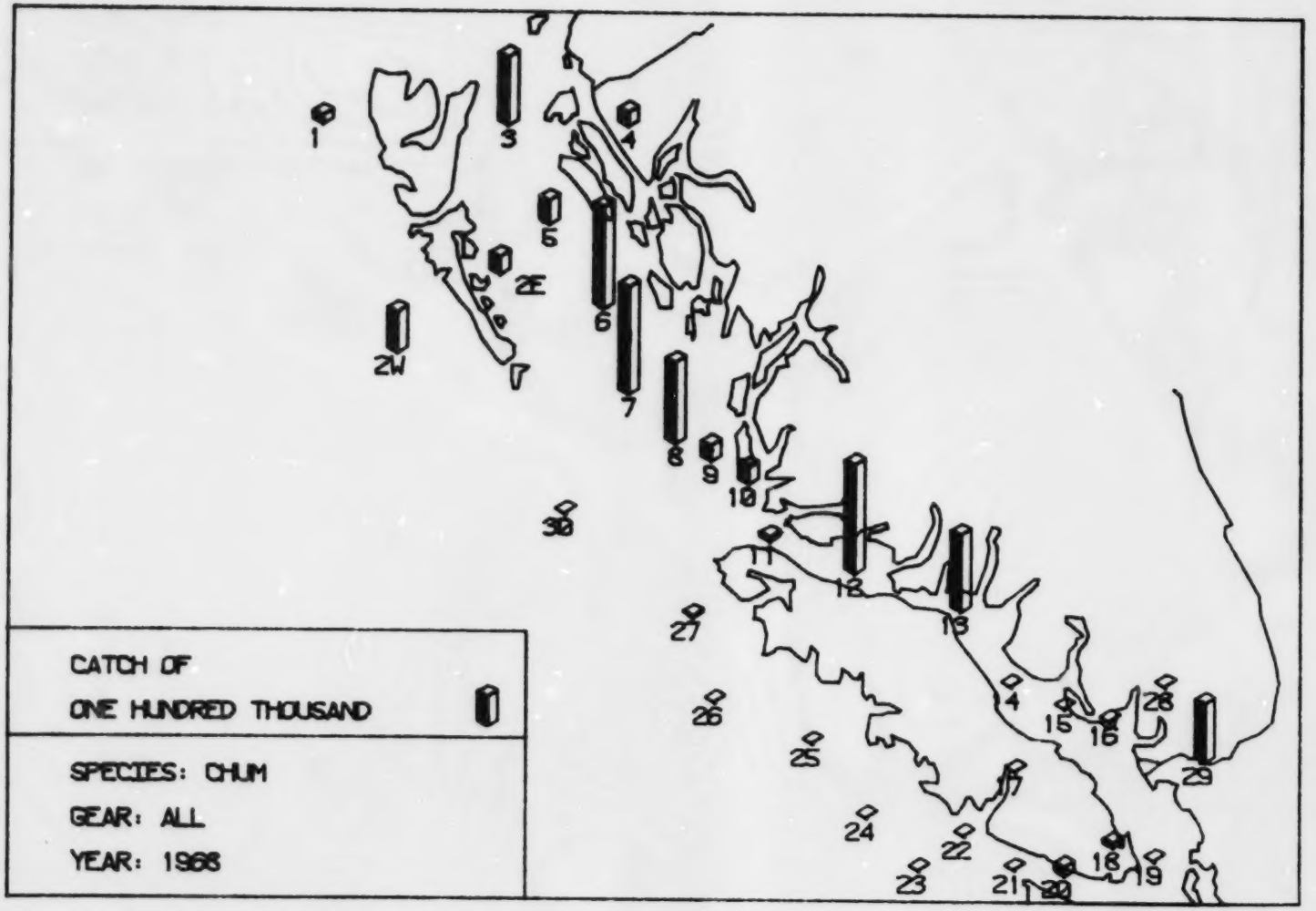

Fig. B18. Catch of chum salmon by Statistical Area in 1968.

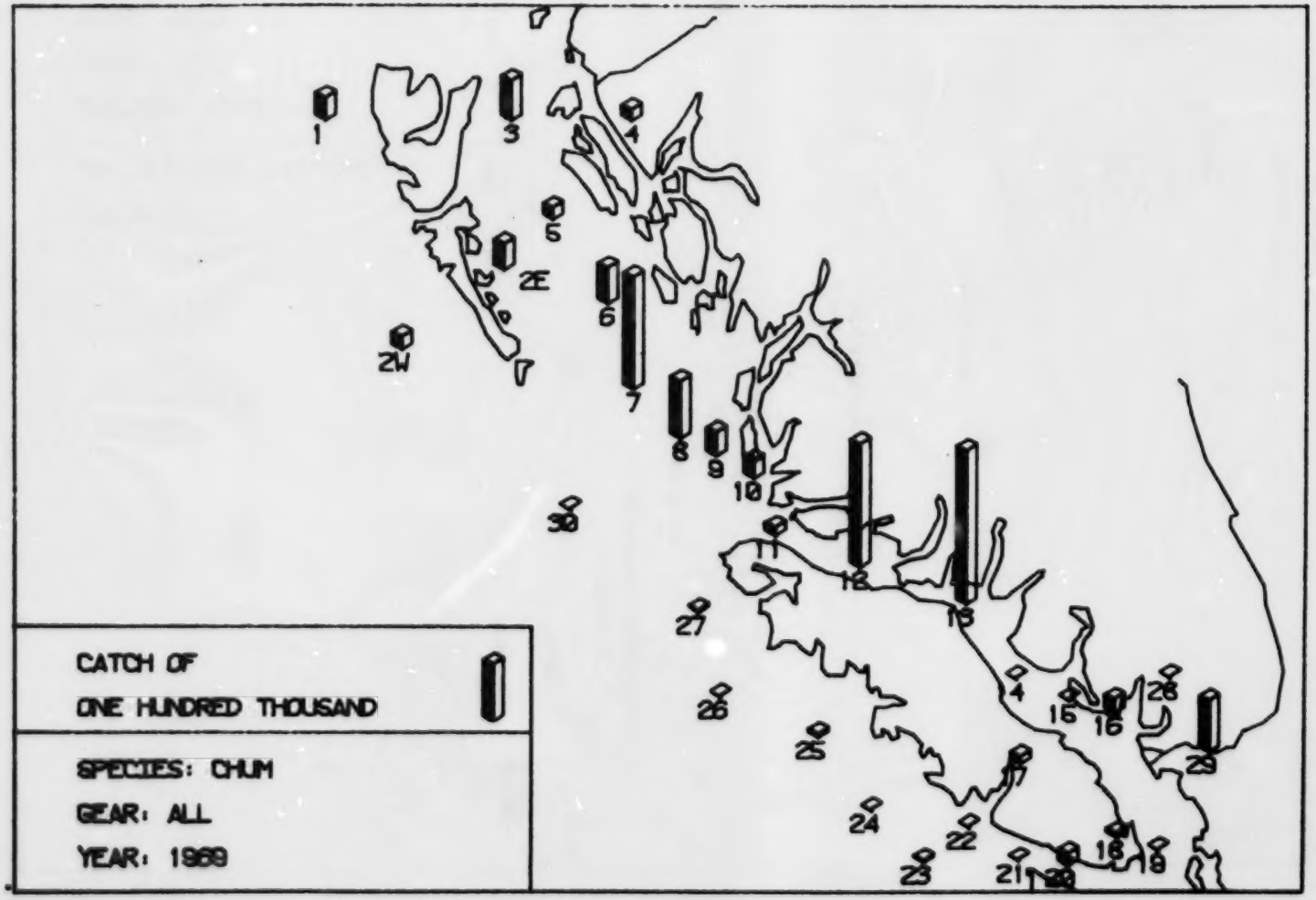

Fig. B19. Catch of chum salmon by Statistical Area in 1969.

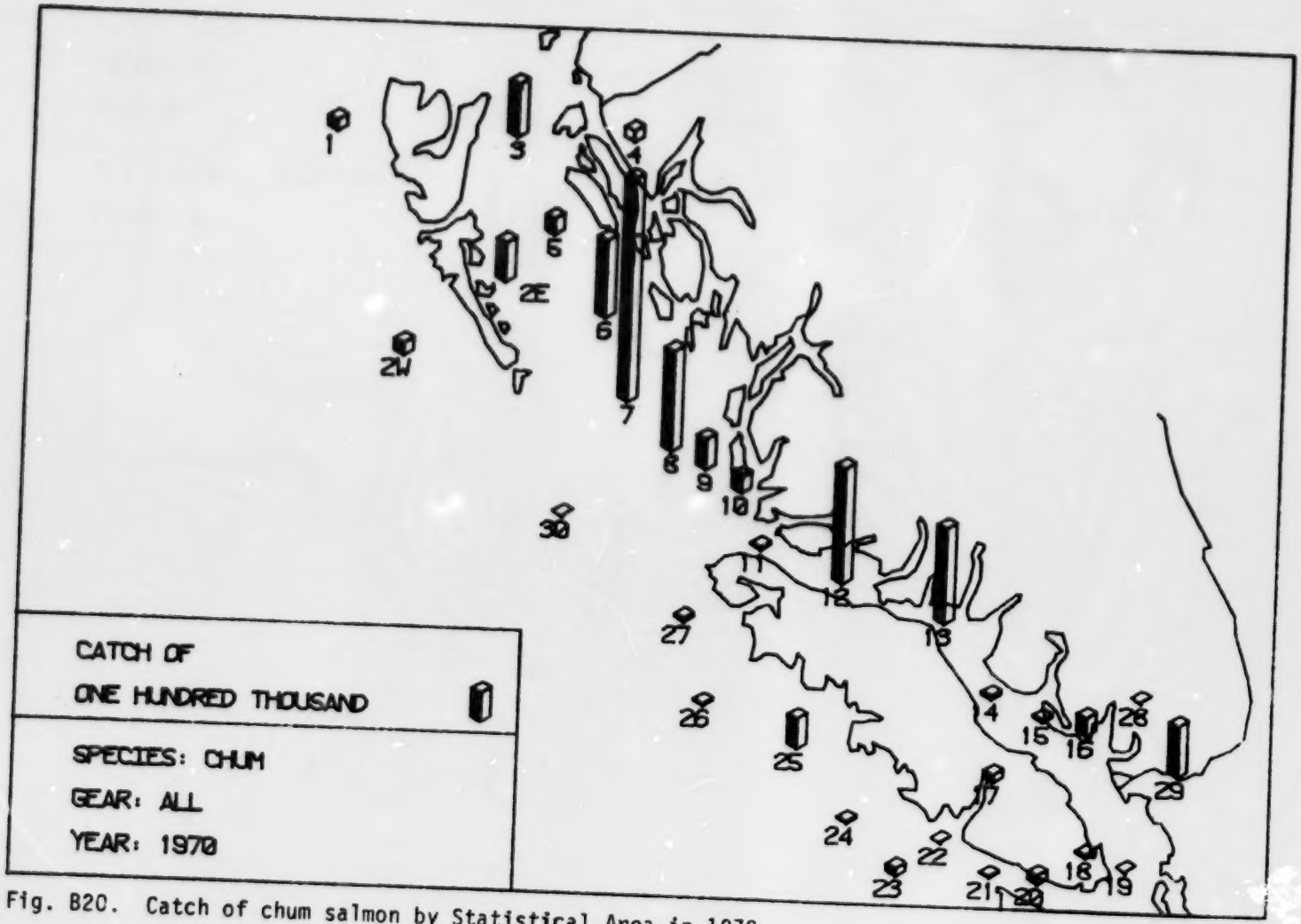

Fig. B20. Catch of chum salmon by Statistical Area in 1970.

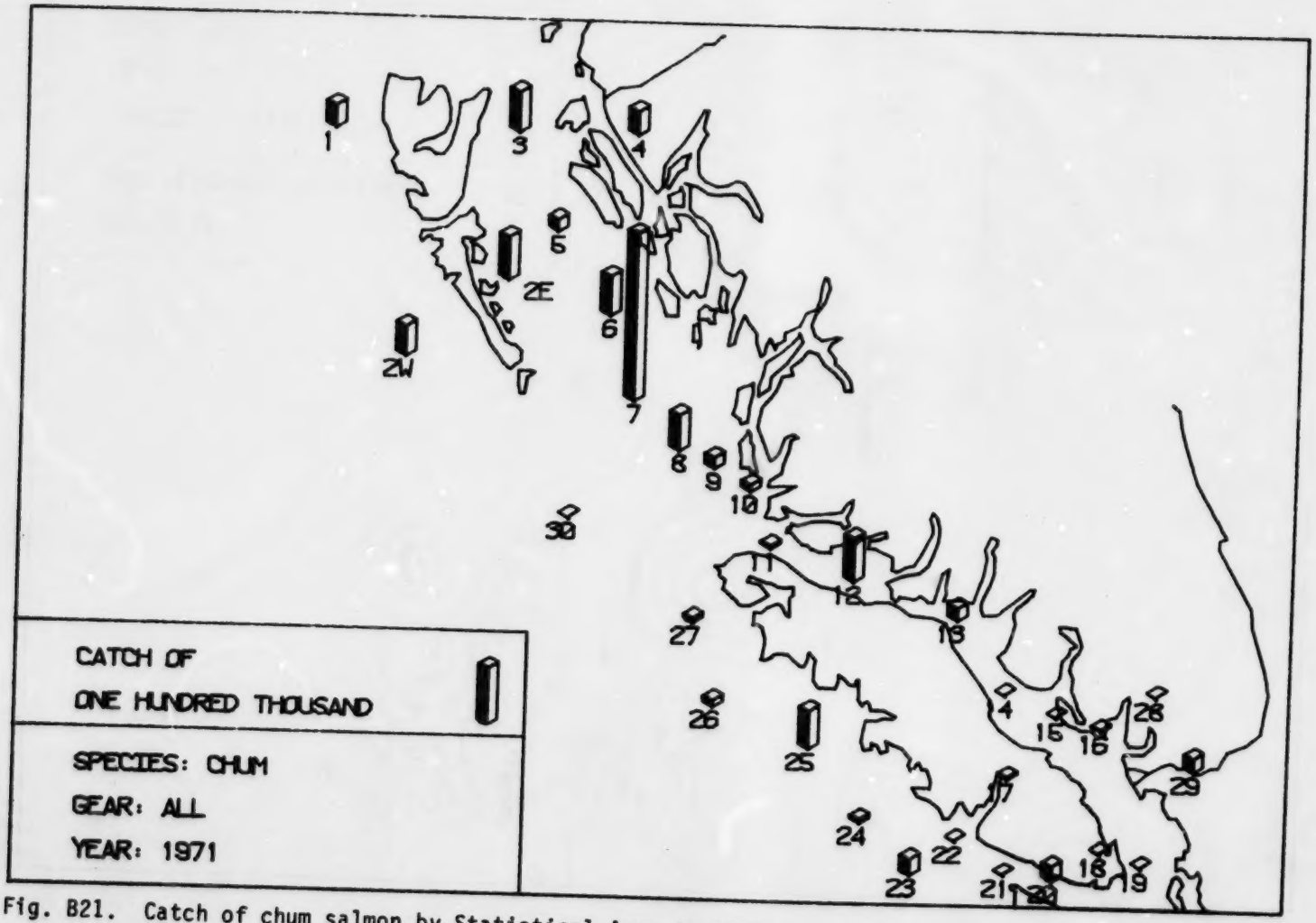

Fig. B21. Catch of chum salmon by Statistical Area in 1971.

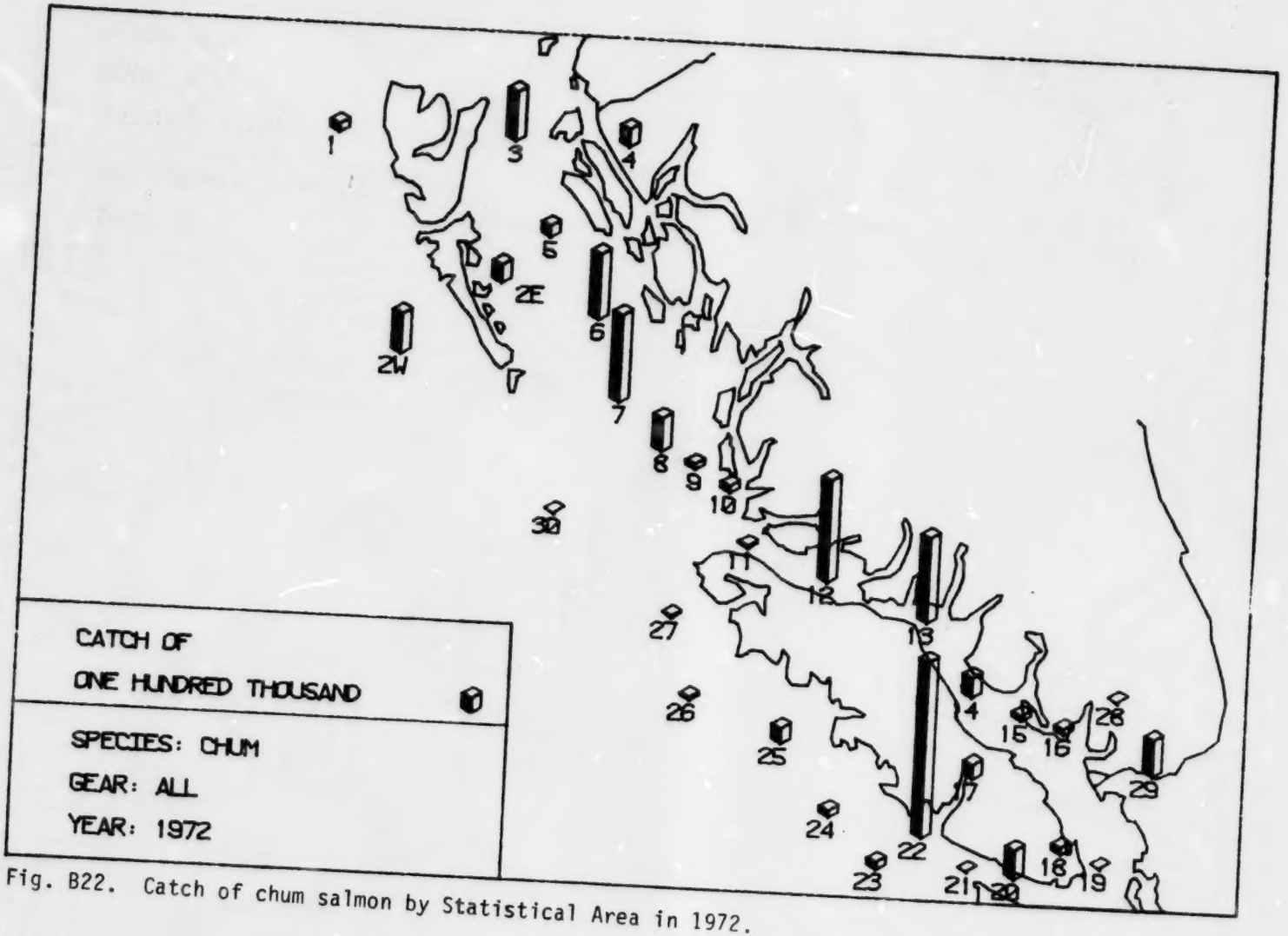

Fig. B22. Catch of chum salmon by Statistical Area in 1972.

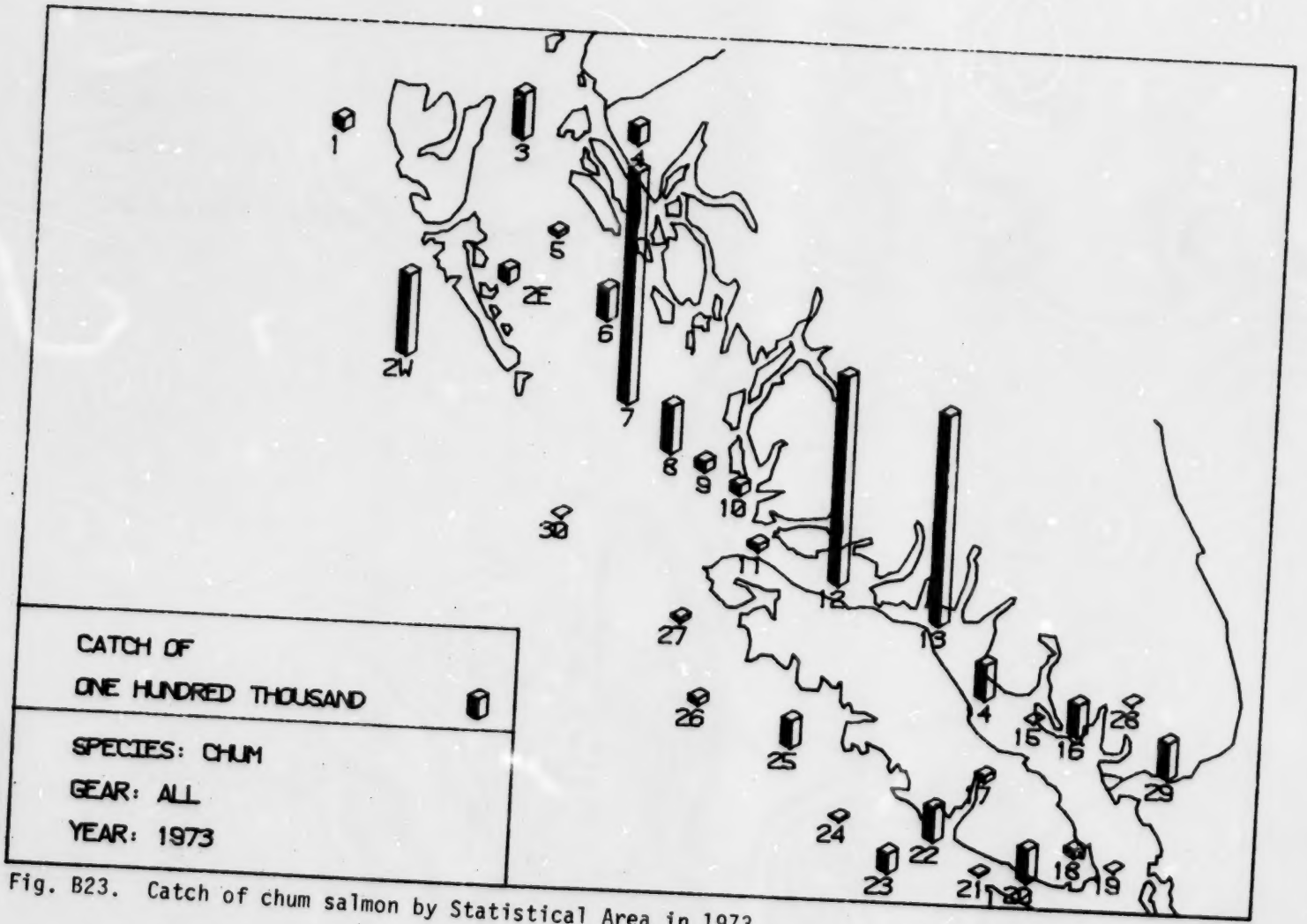

Fig. B23. Catch of chum salmon by Statistical Area in 1973.

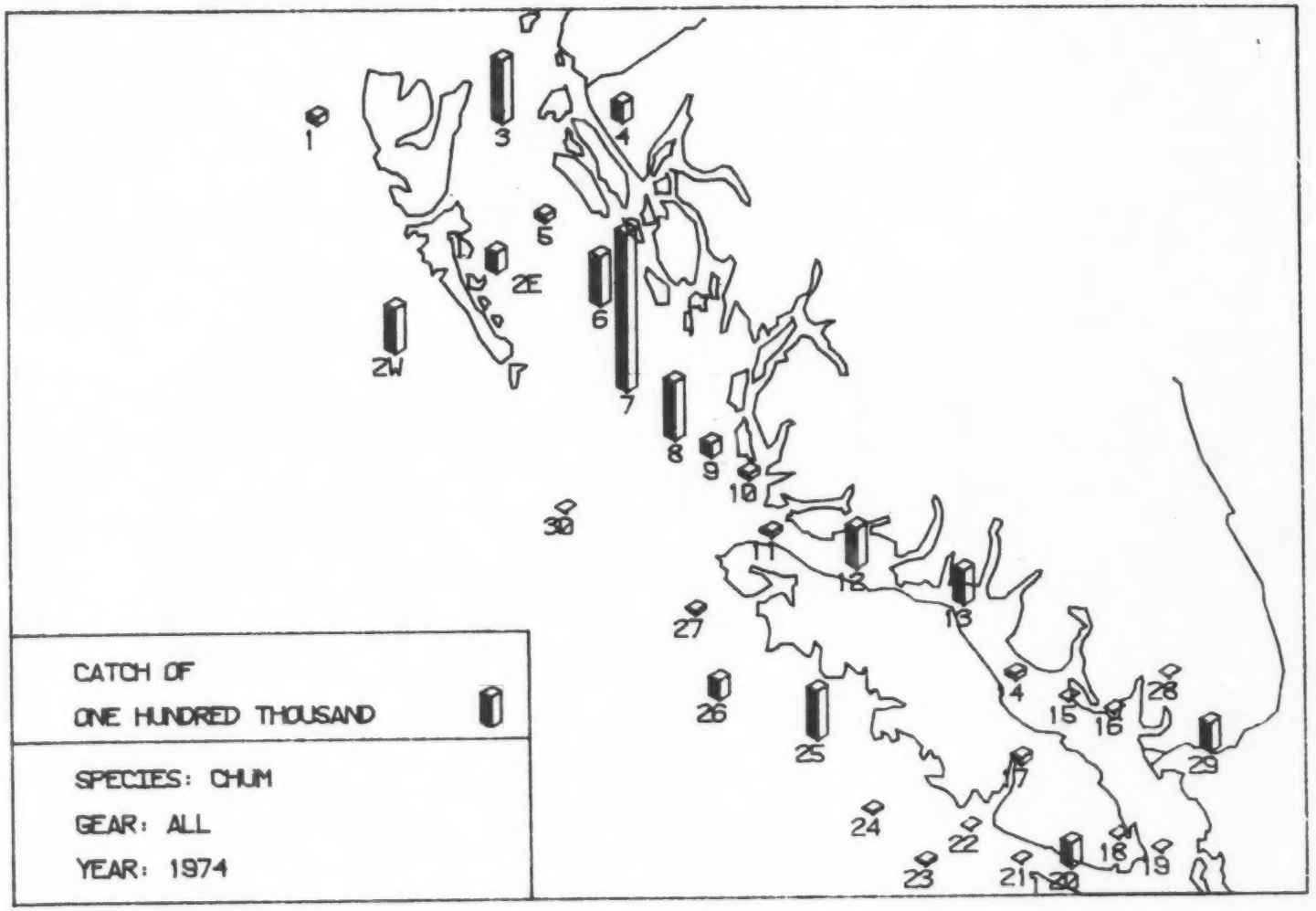

Fig. B24. Catch of chum salmon by Statistical Area in 1974.

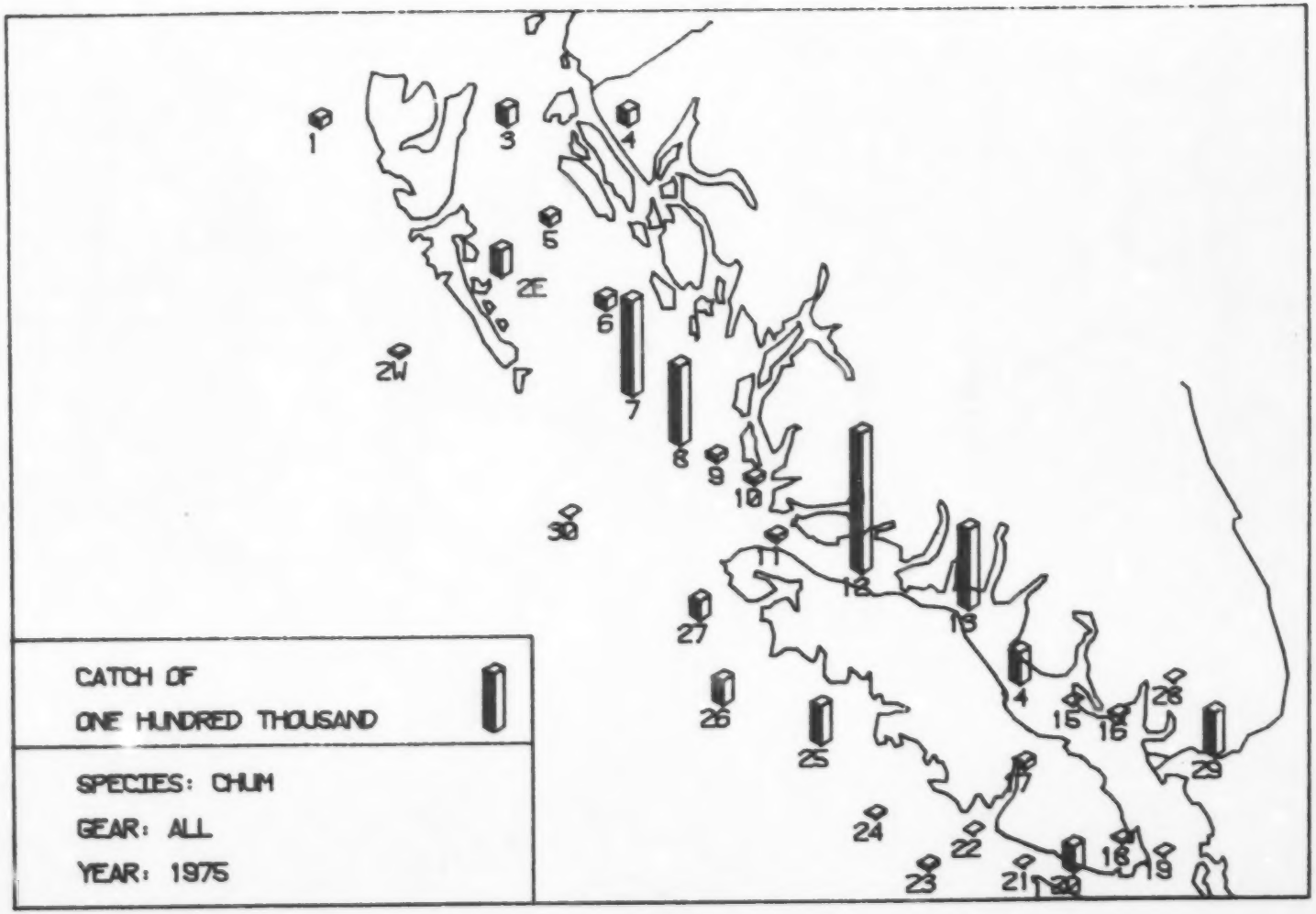

Fig. B25. Catch of chum salmon by Statistical Area in 1975.

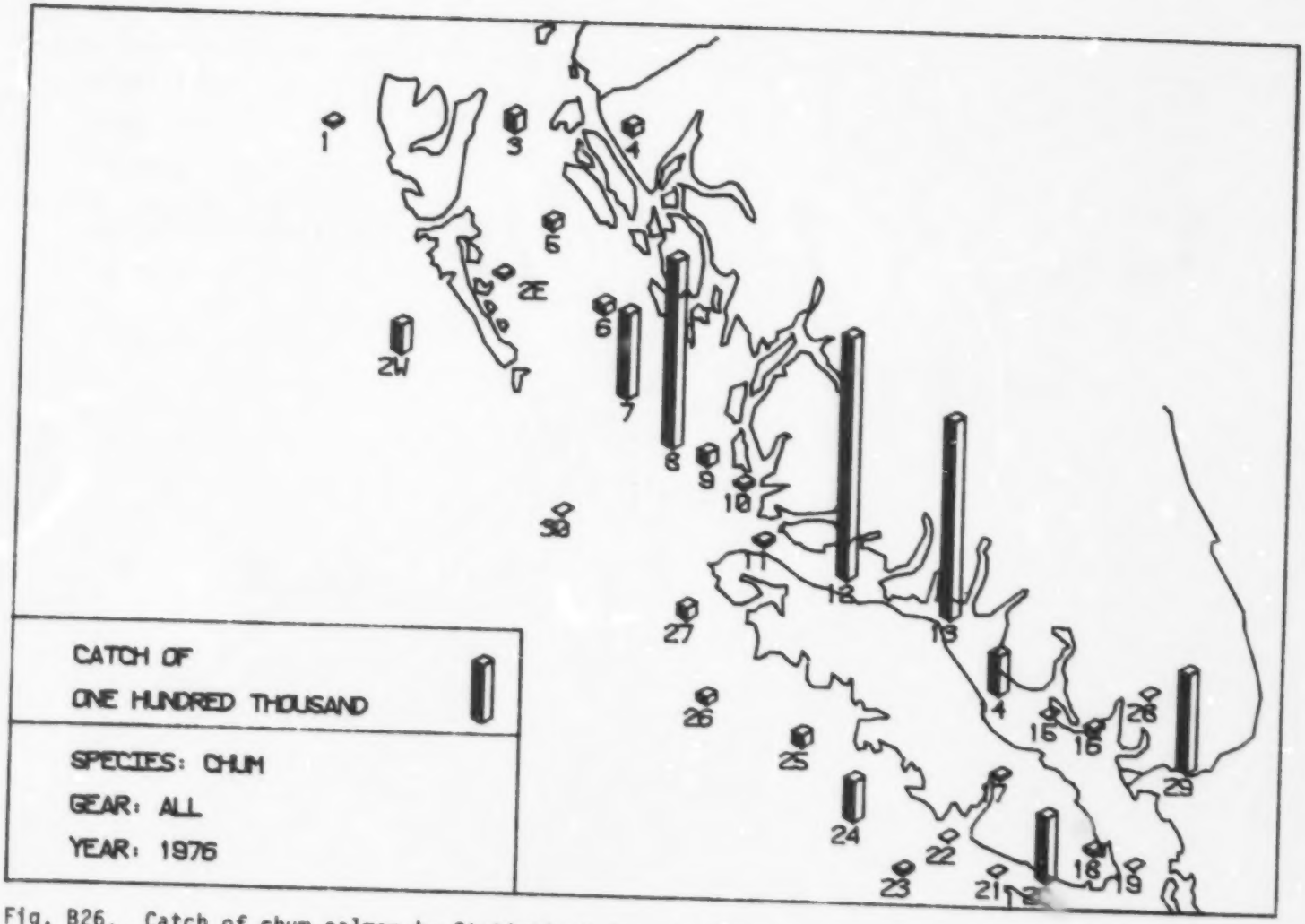

Fig. B26. Catch of chum salmon by Statistical Area in 1976.

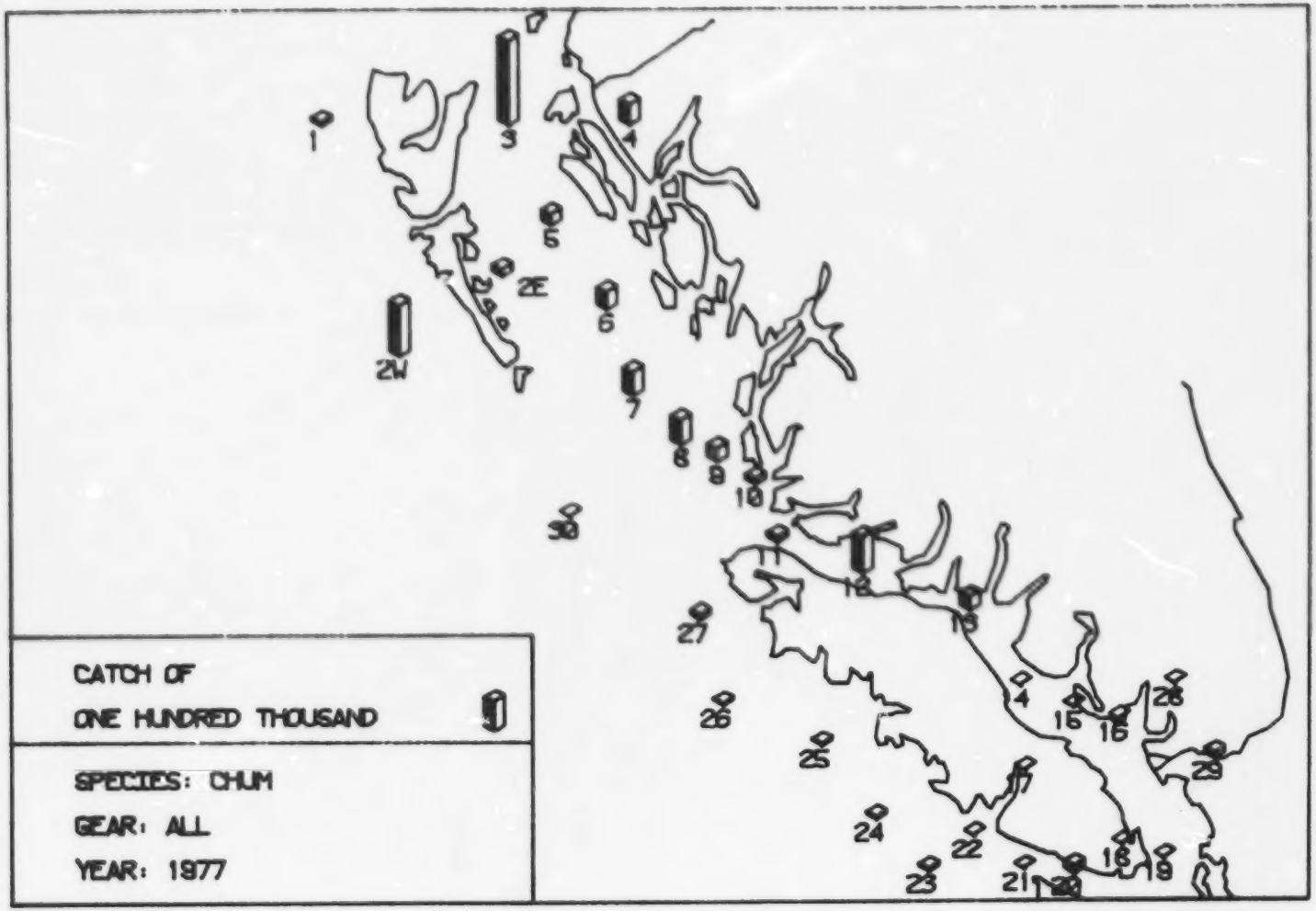

Fig. B27. Catch of chum salmon by Statistical Area in 1977.

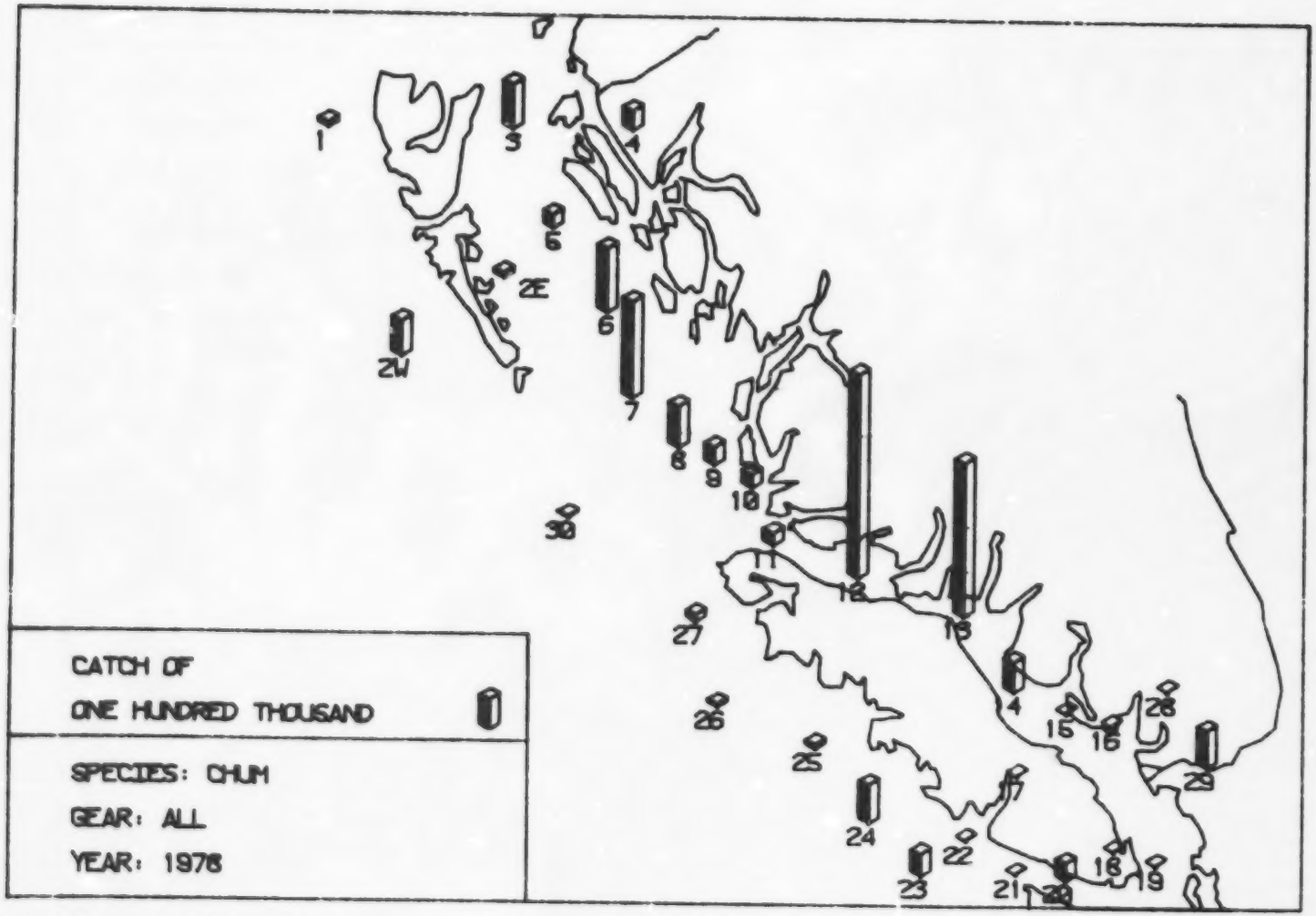

Fig. B28. Catch of chum salmon by Statistical Area in 1978.

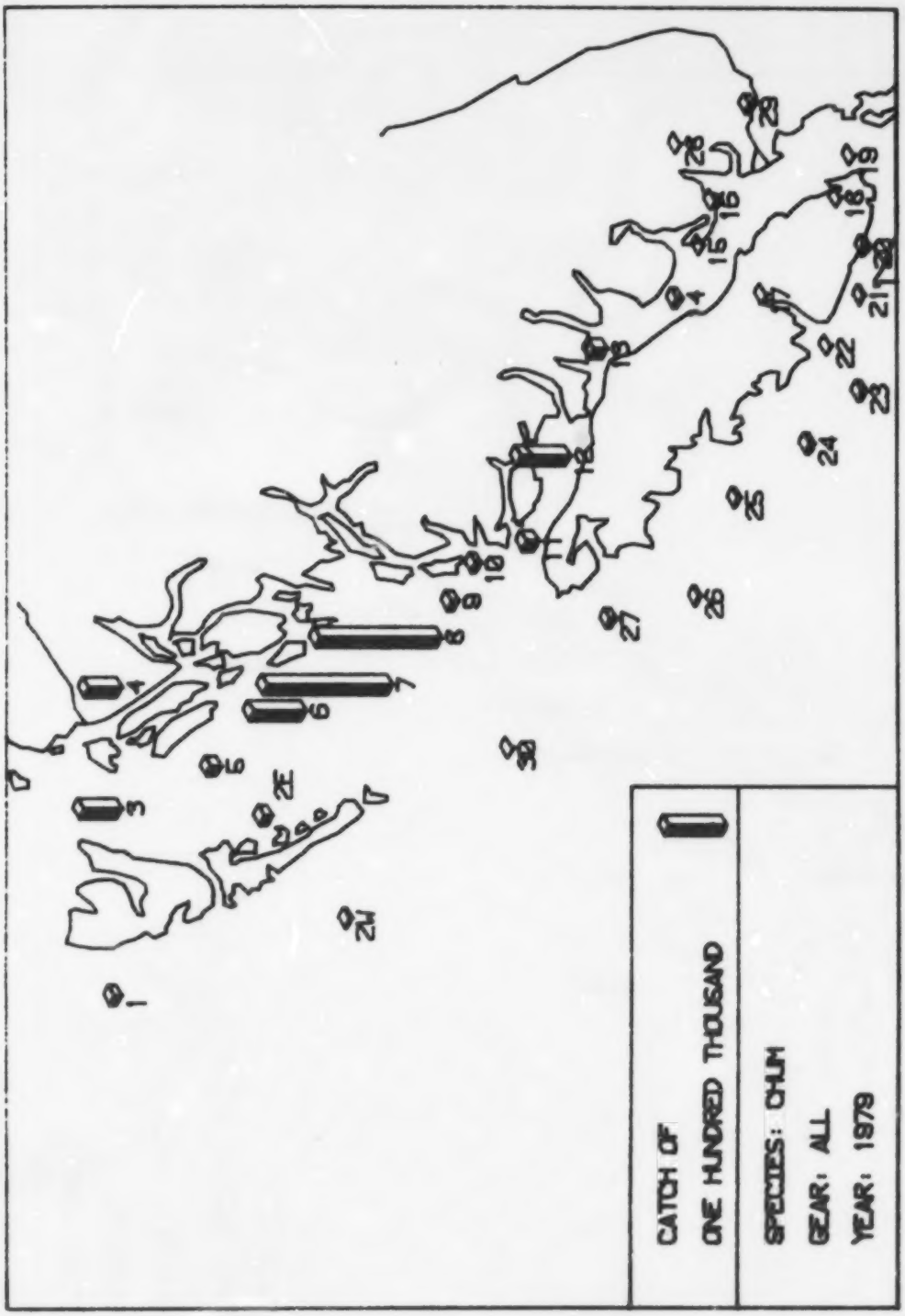

Fig. B29. Catch of chum salmon by Statistical Area in 1979.

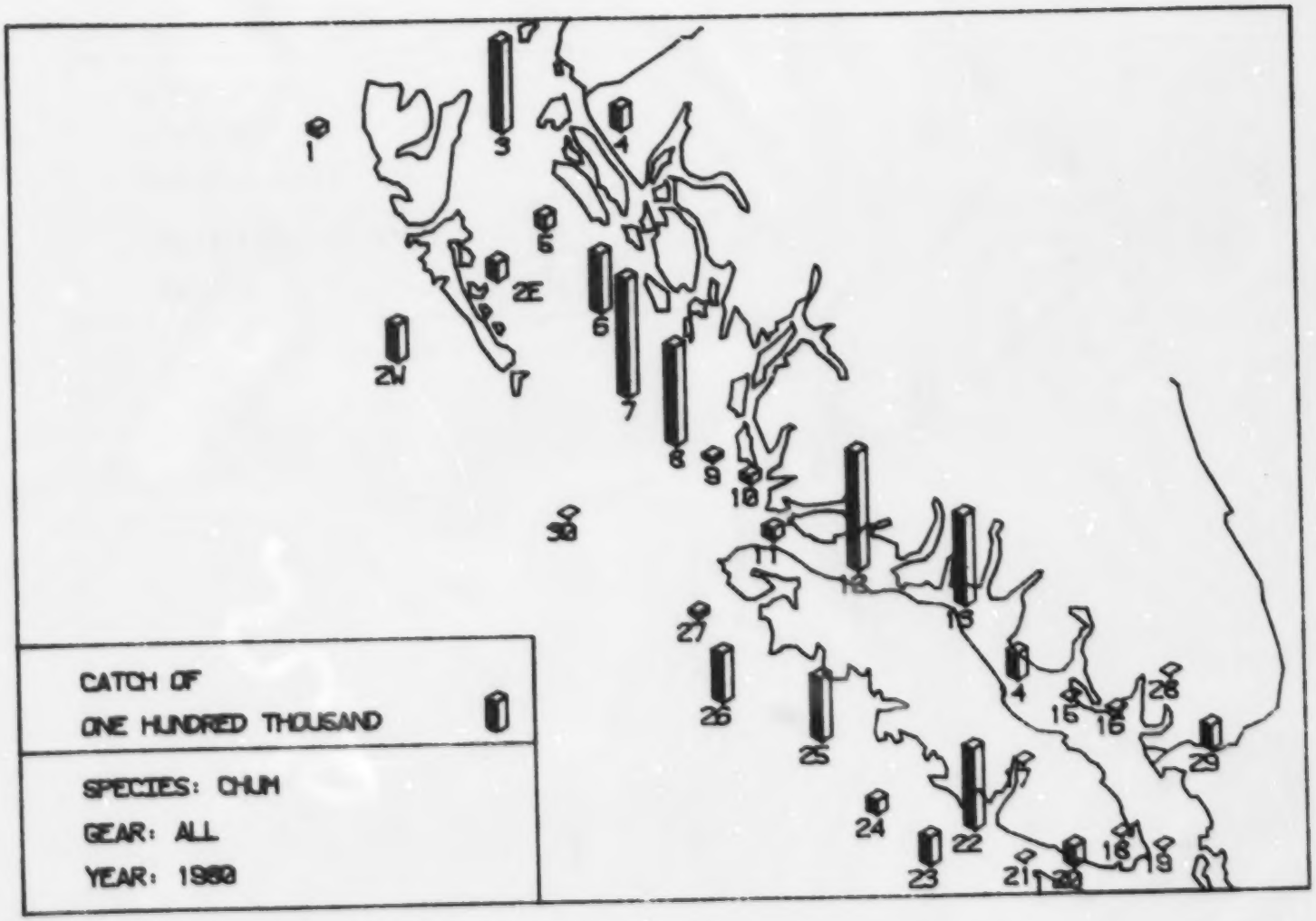

Fig. B30. Catch of chum slamon by Statistical Area in 1980.

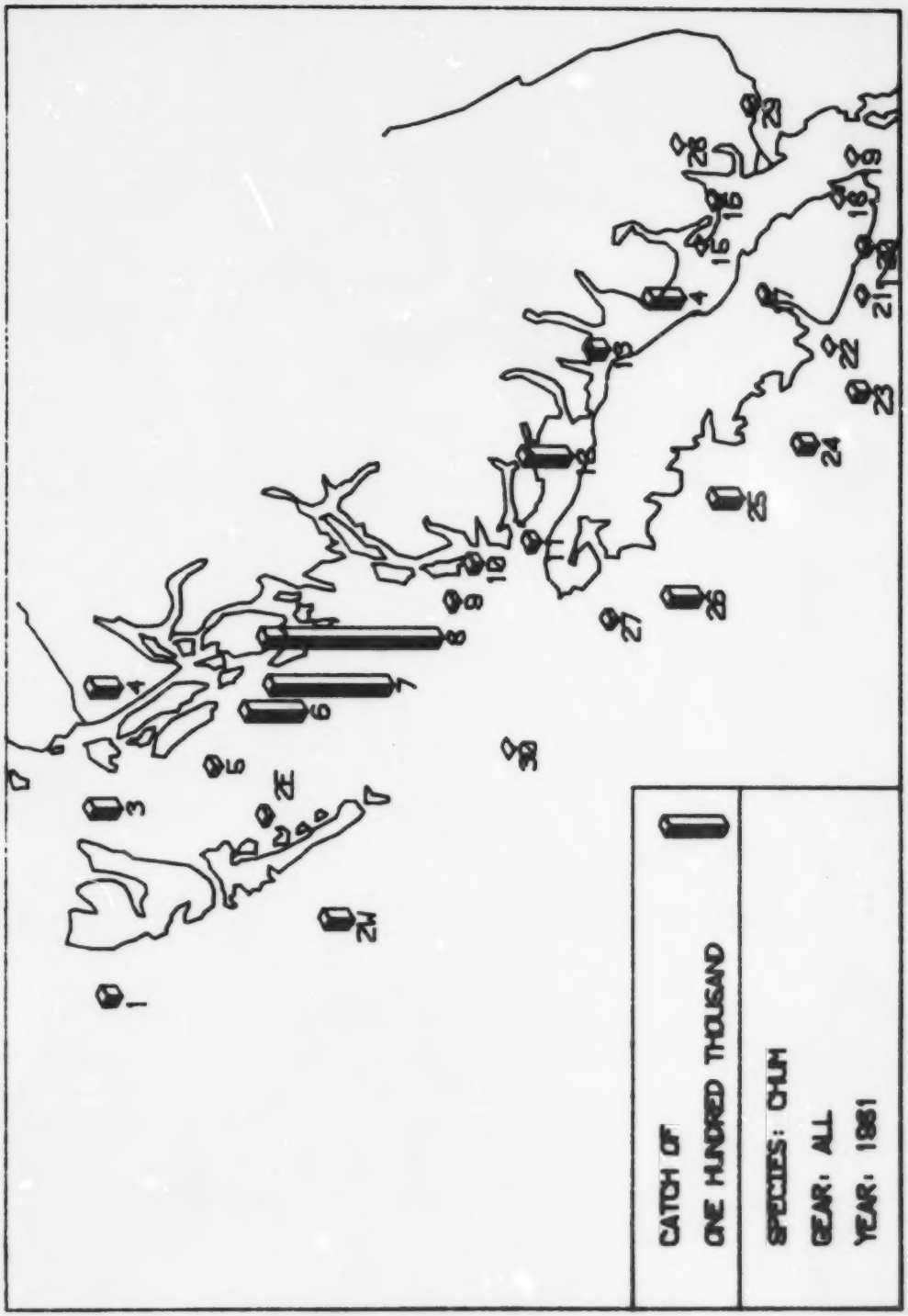

Fig. B31. Catch of chum salmon by Statistical Area in 1981.

APPENDIX C

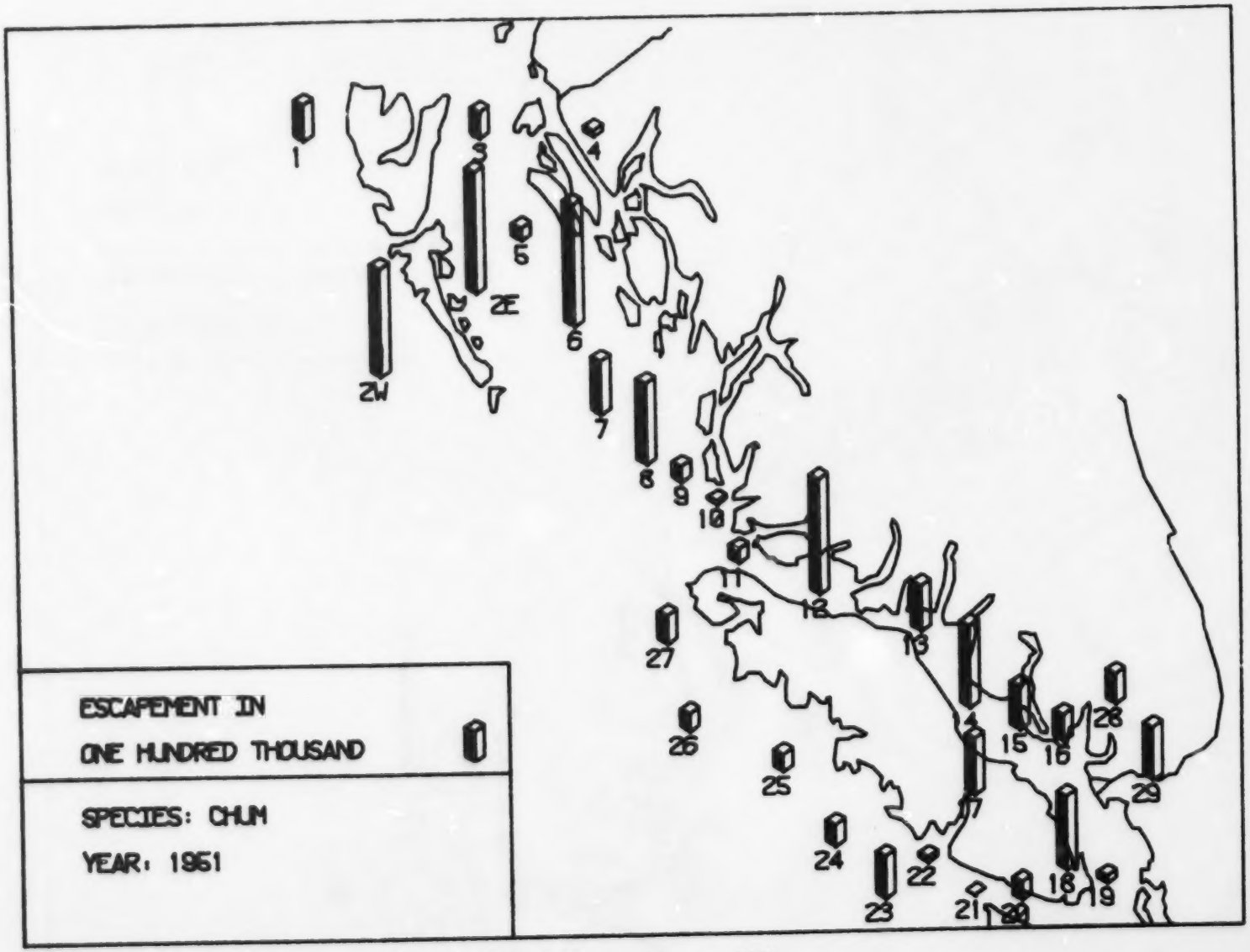

Fig. C1. Escapement of chum salmon by Statistical Area in 1951.

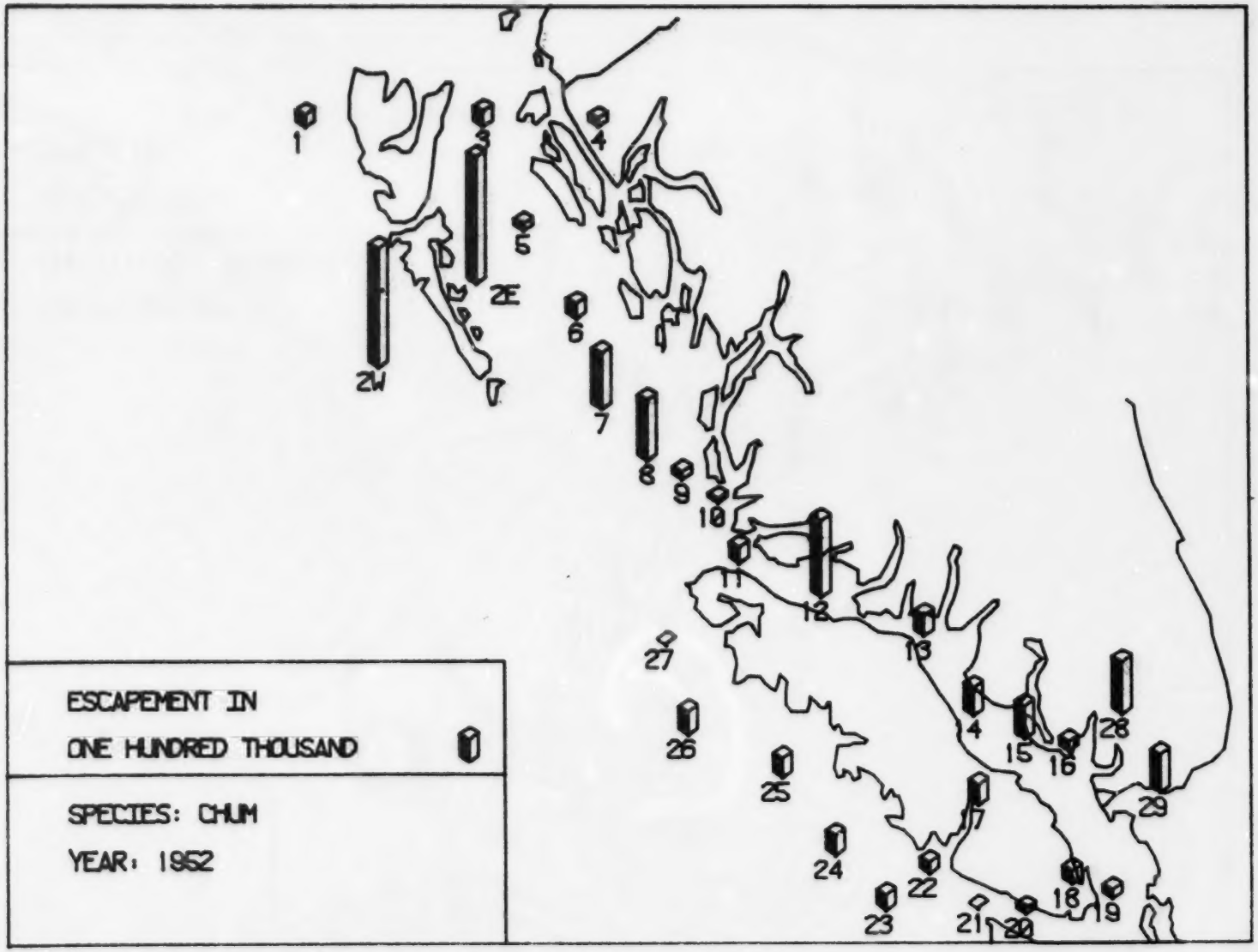

Fig. C2. Escapement of chum salmon by Statistical Area in 1952.

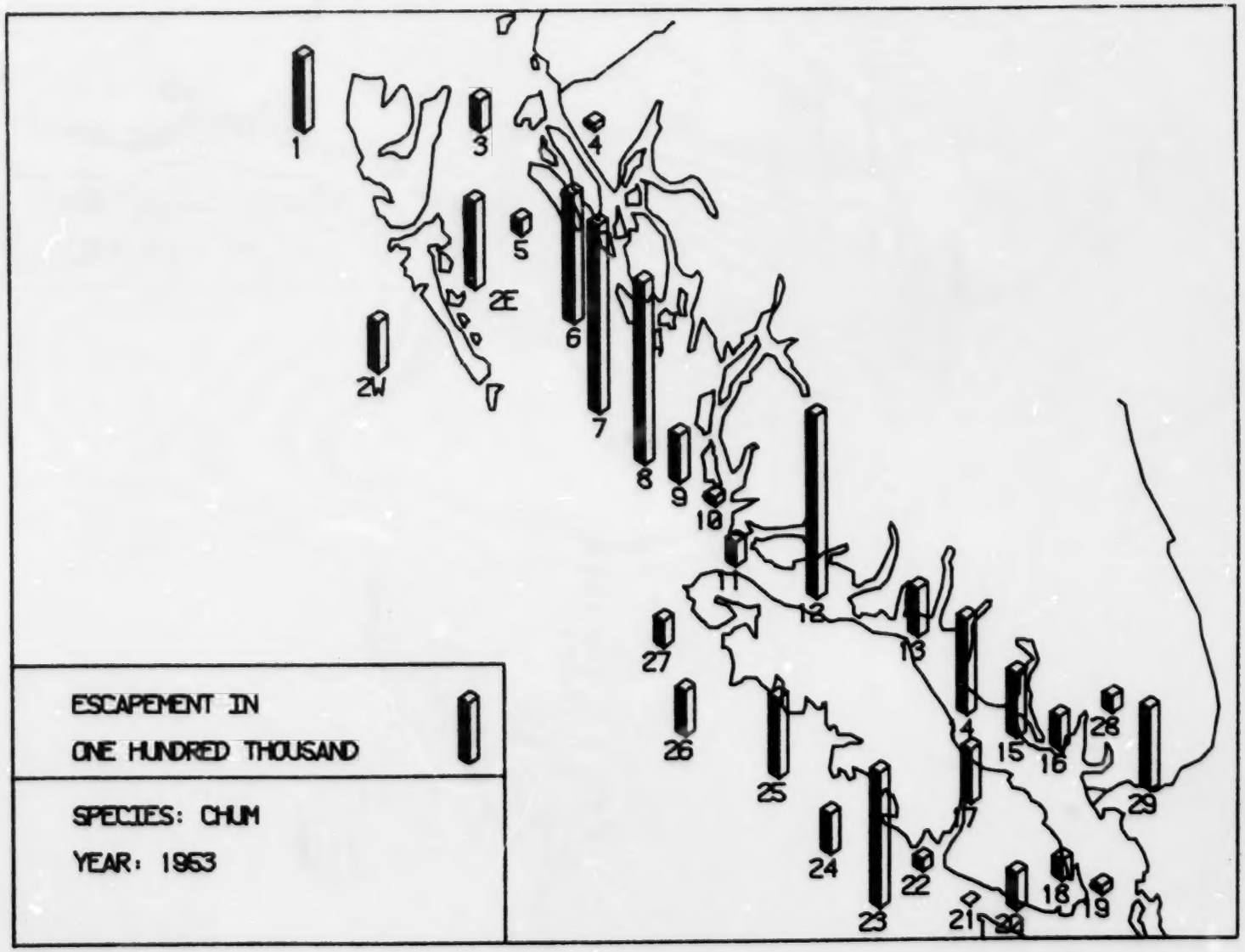

Fig. C3. Escapement of chum salmon by Statistical Area in 1953.

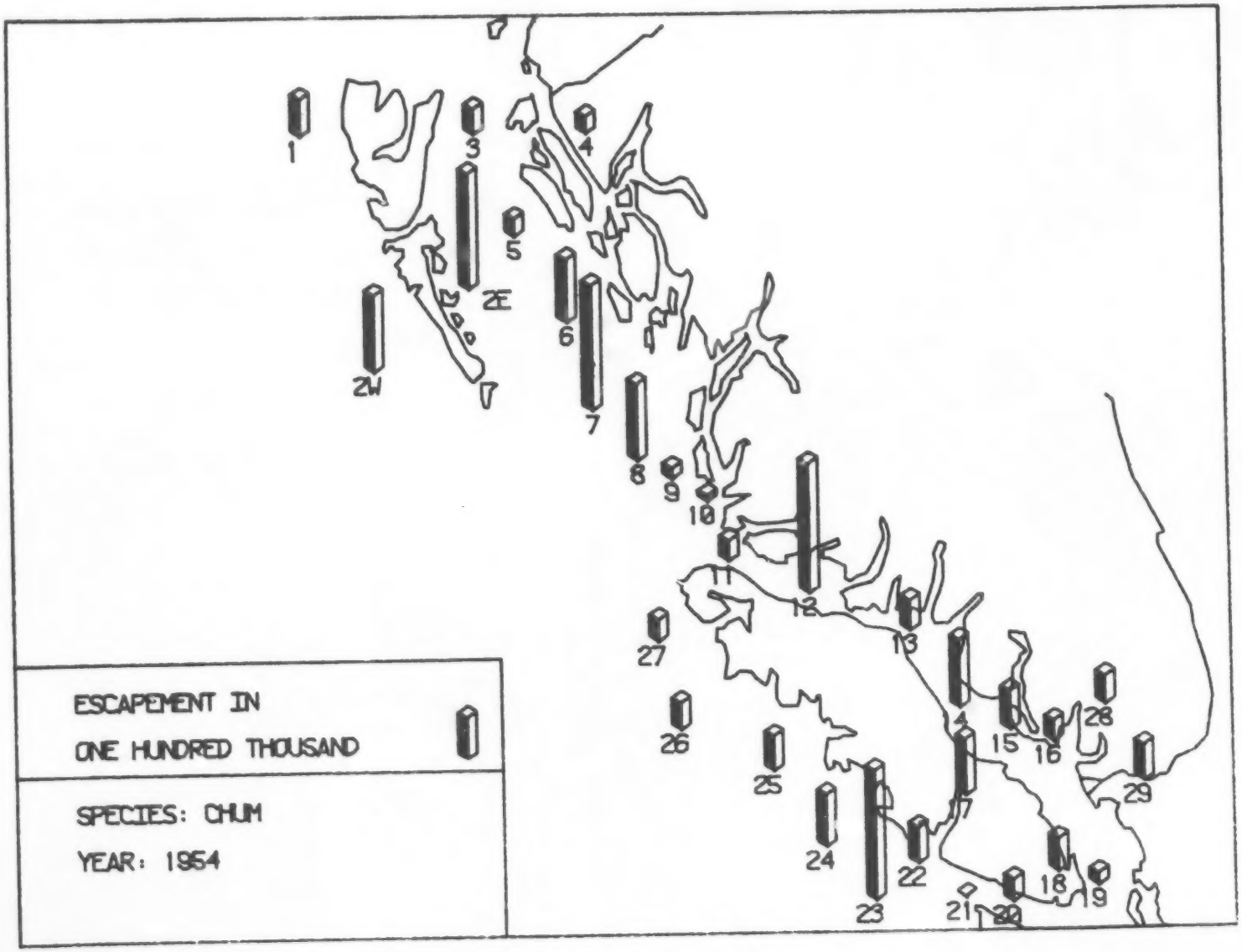

Fig. C4. Escapement of chum salmon by Statistical Area in 1954.

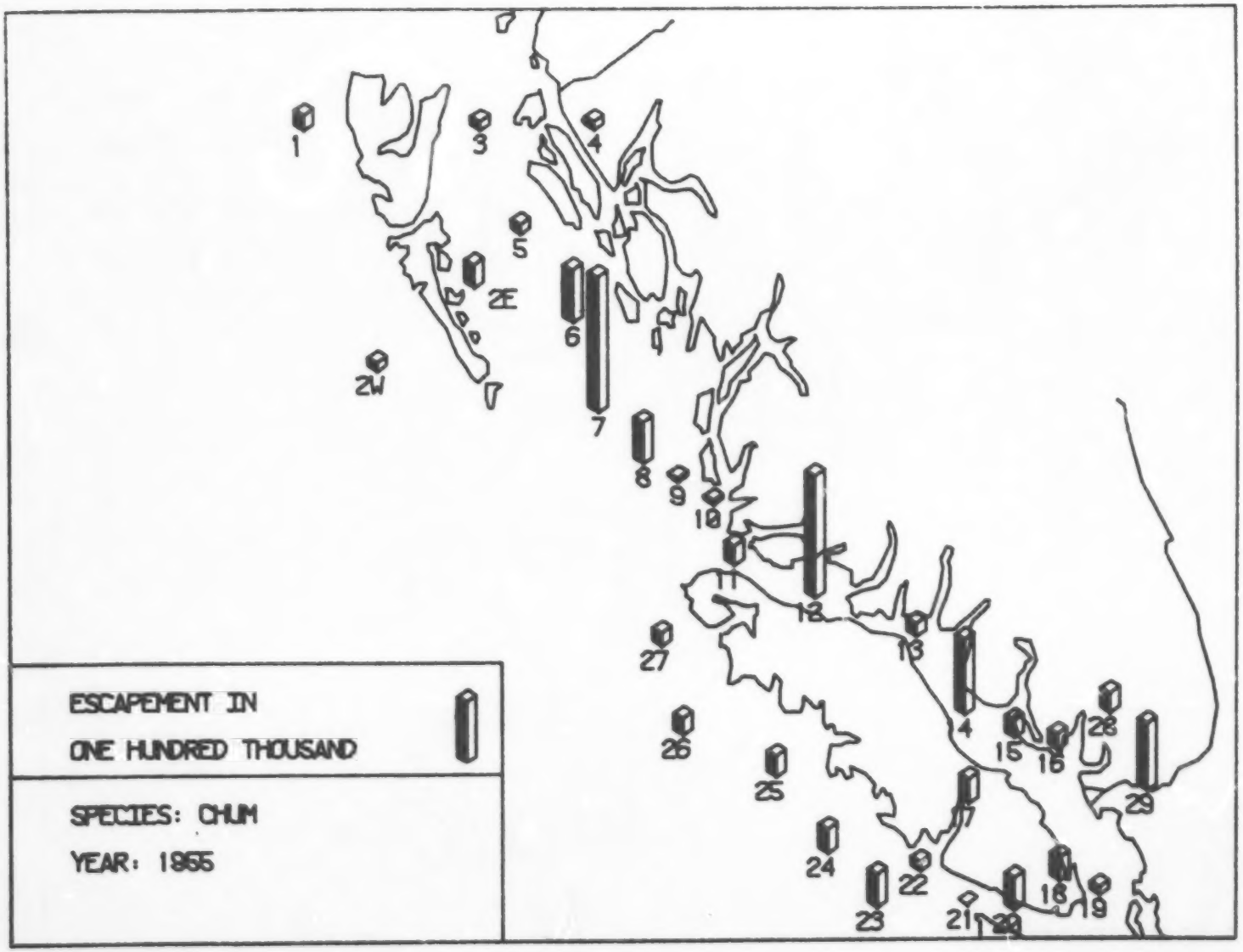

Fig. C5. Escapement of chum salmon by Statistical Area in 1955.

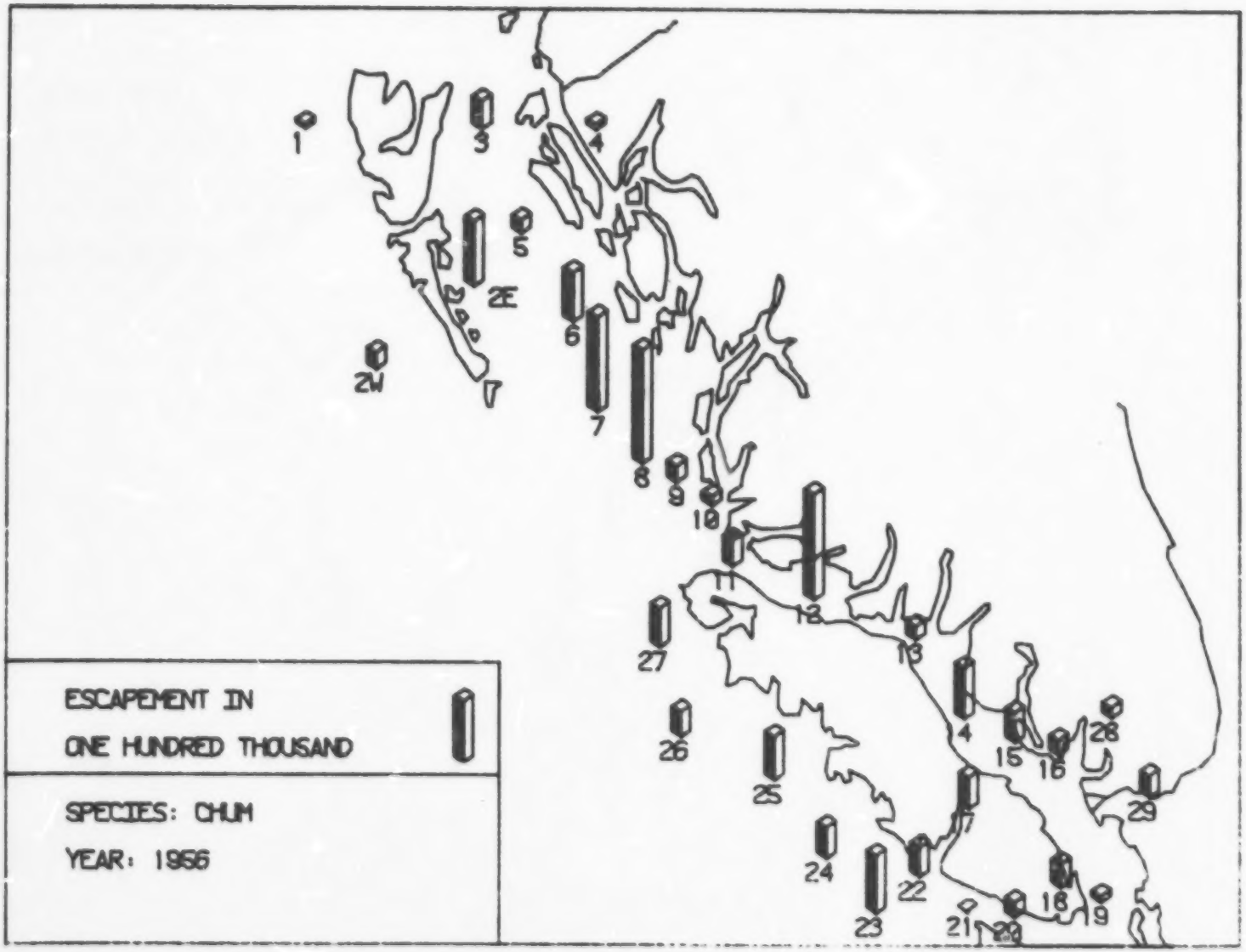

Fig. C6. Escapement of chum salmon by Statistical Area in 1956.

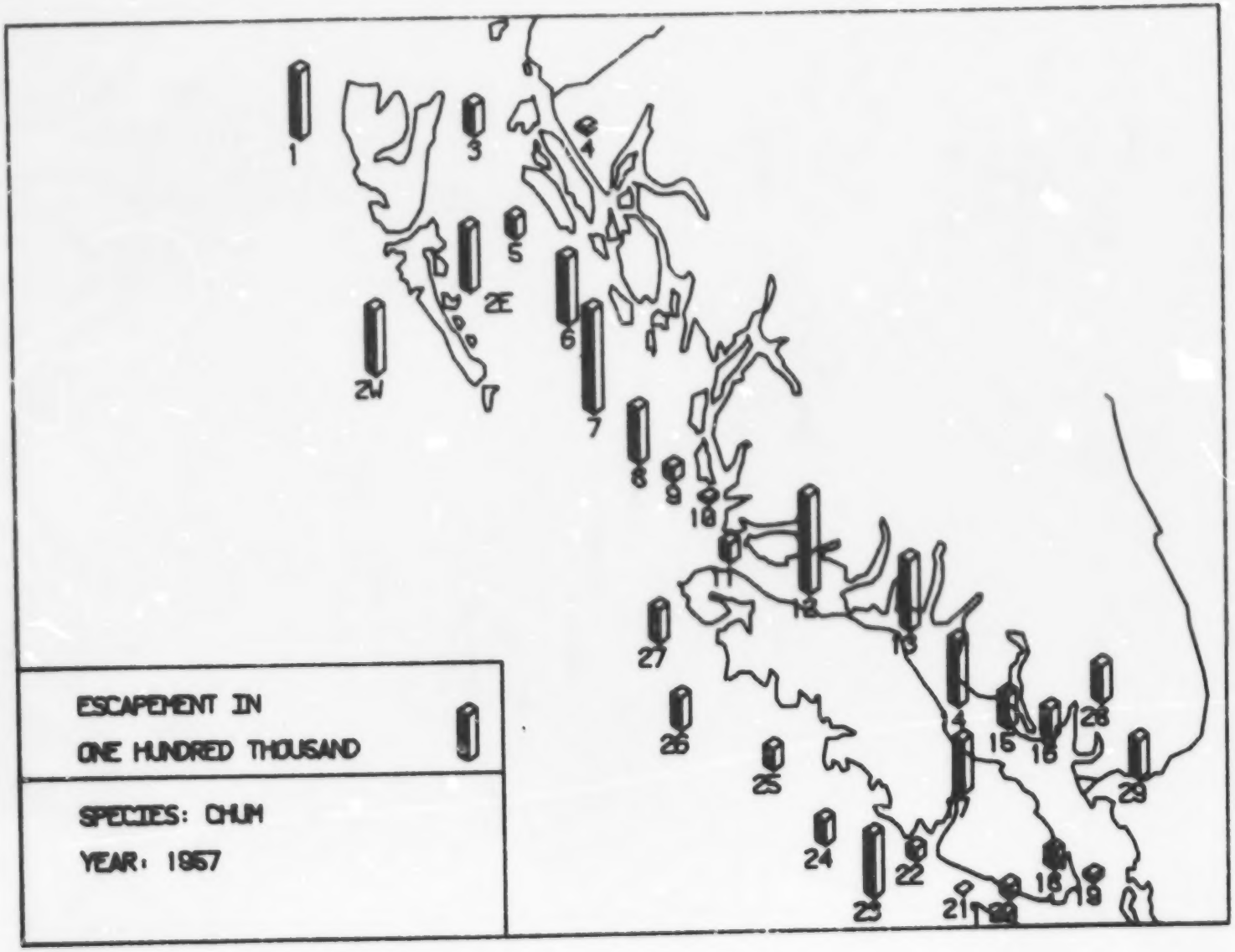

Fig. C7. Escapement of chum salmon by Statistical Area in 1957.

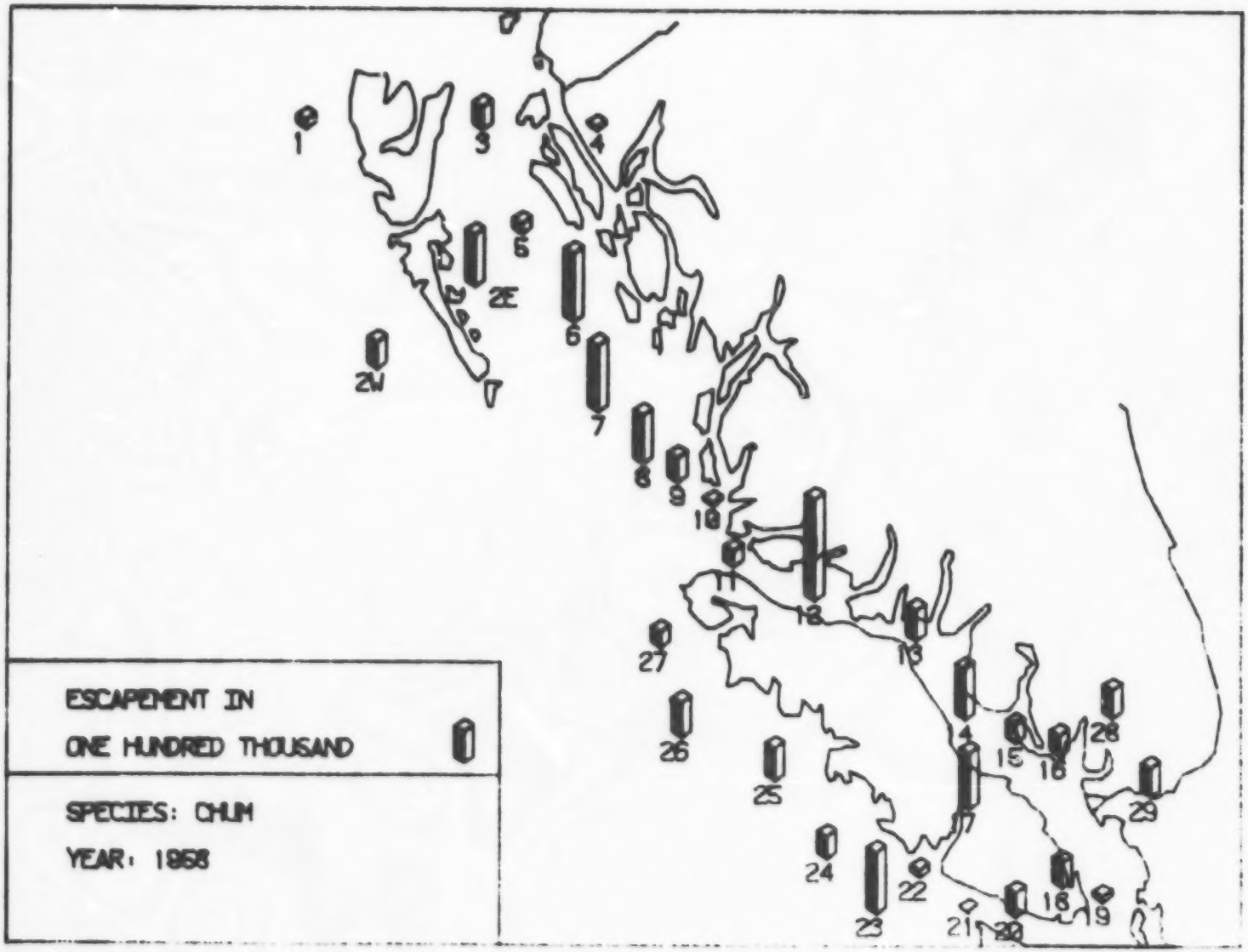

Fig. C8. Escapement of chum salmon by Statistical Area in 1958.

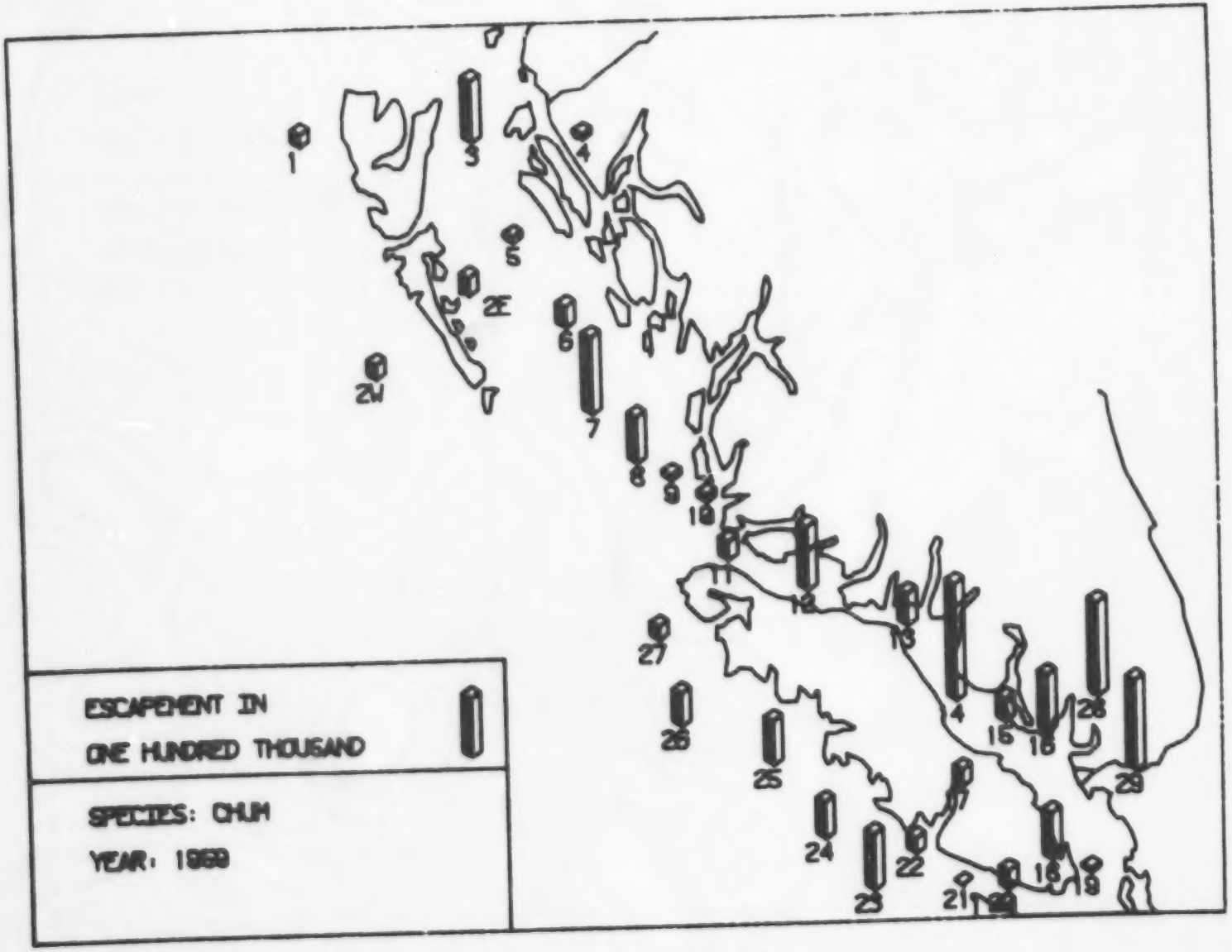

Fig. C9. Escapement of chum salmon by Statistical Area in 1959.

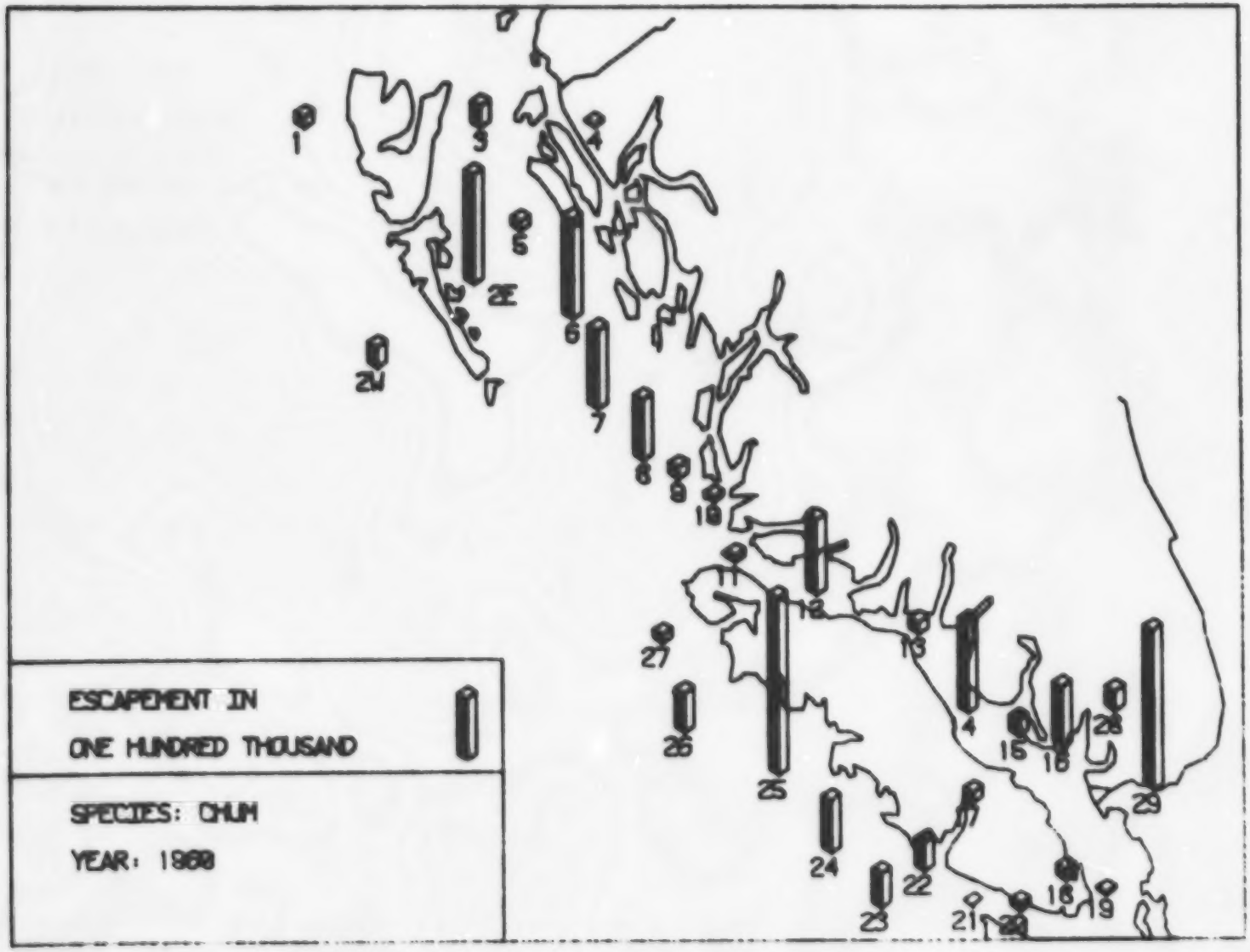

Fig. C10. Escapement of chum salmon by Statistical Area in 1980.

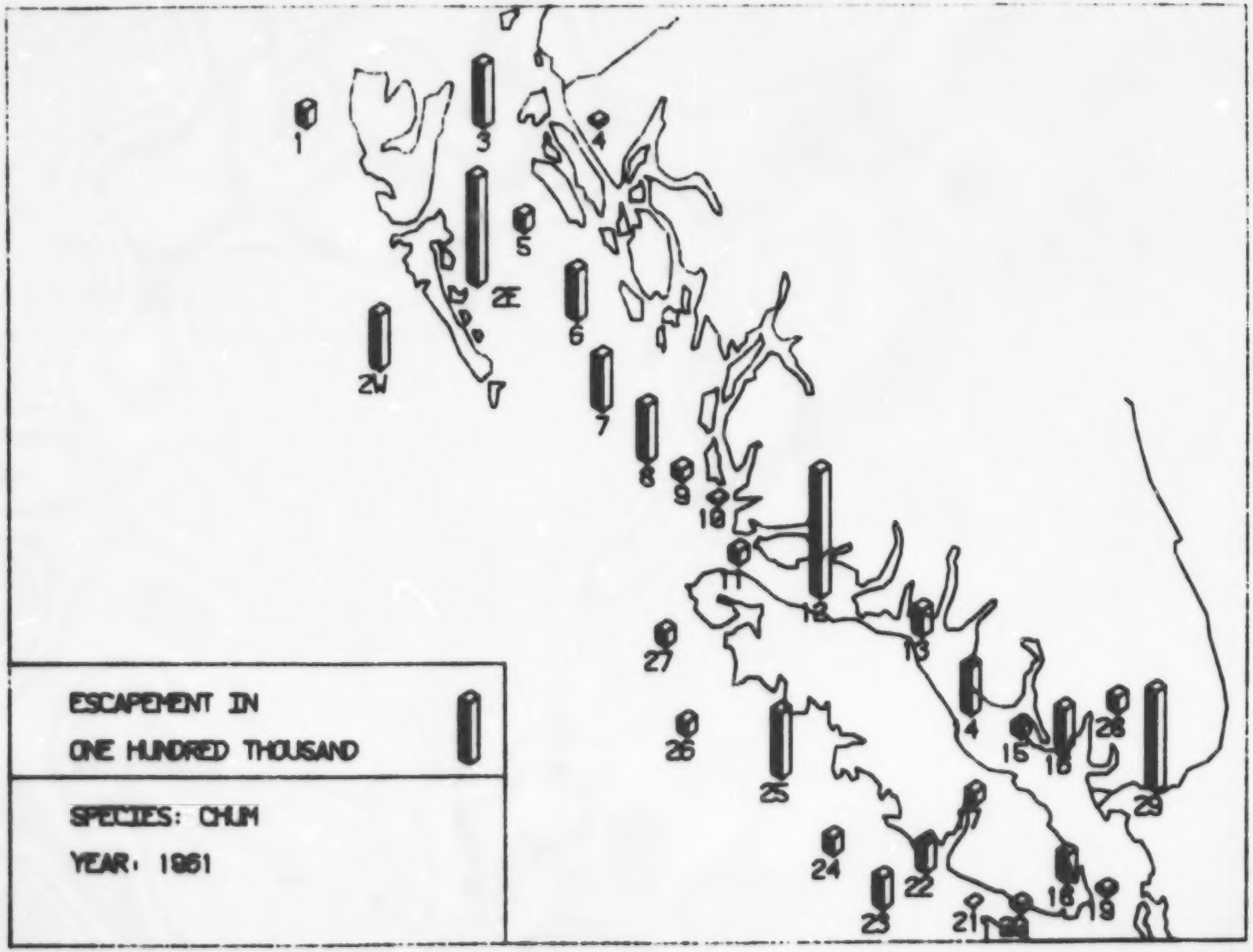

Fig. C11. Escapement of chum salmon by Statistical Area in 1961.

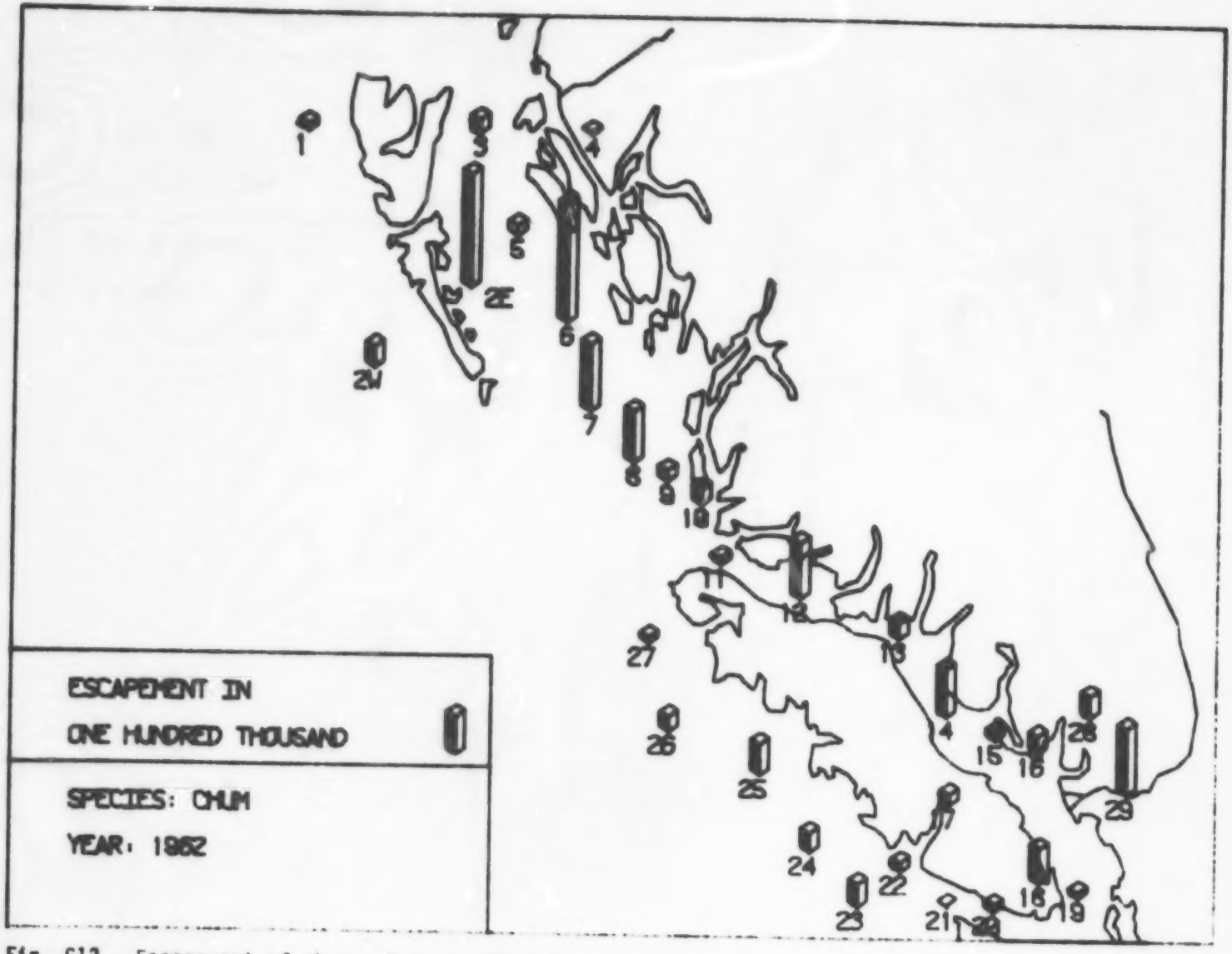

Fig. C12. Escapement of chum salmon by Statistical Area in 1962.

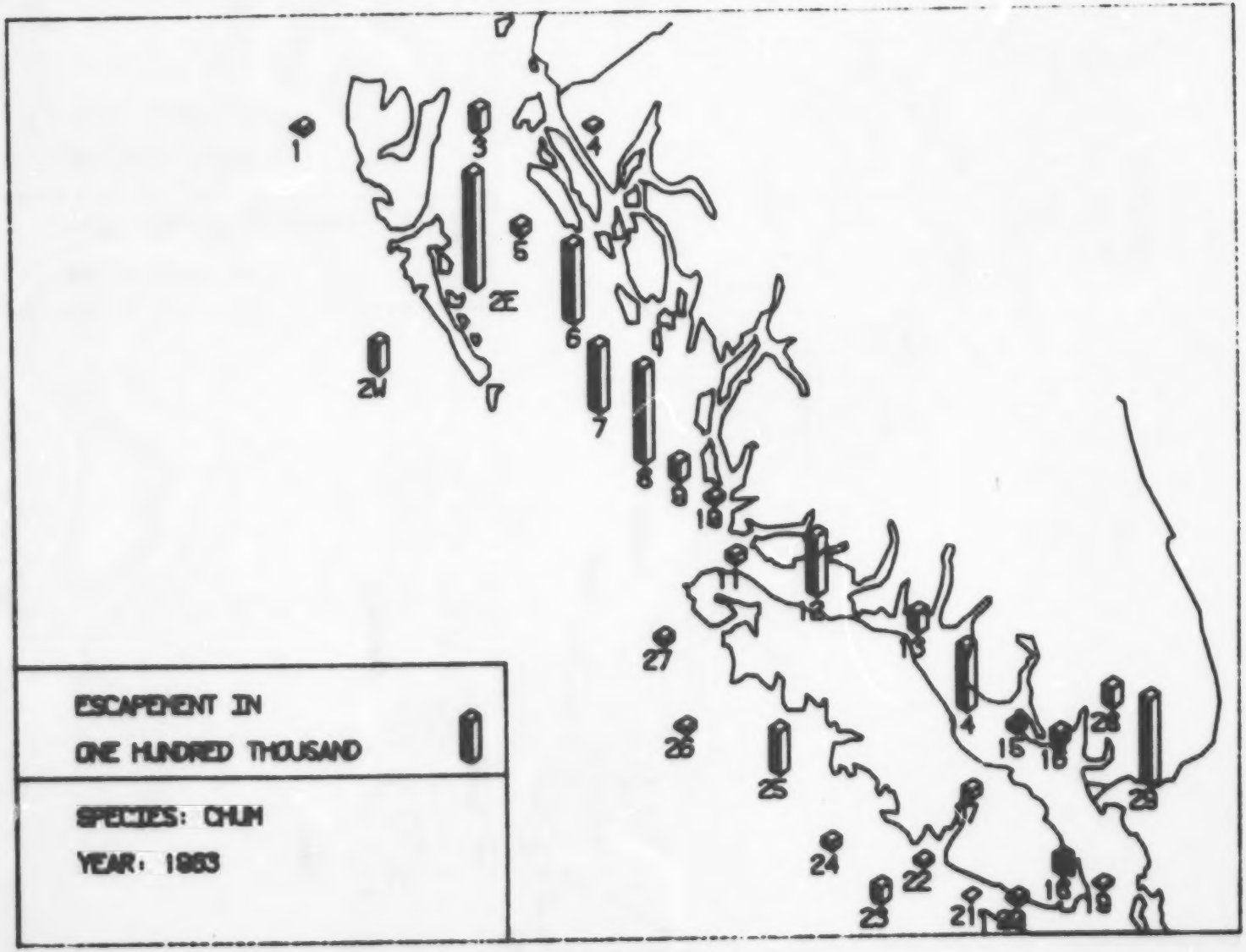

Fig. C13. Escapement of chum salmon by Statistical Area in 1963.

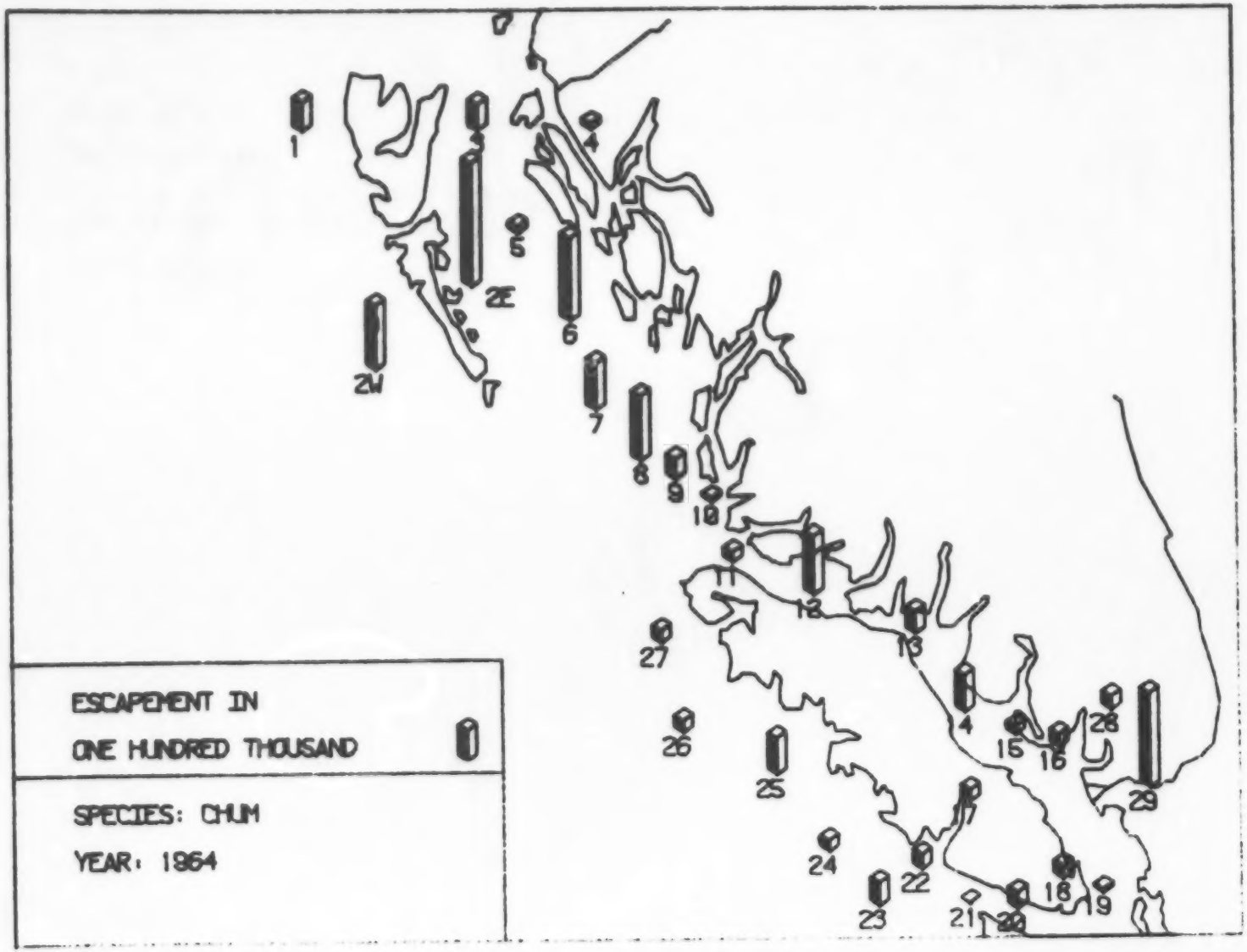

Fig. C14. Escapement of chum salmon by Statistical Area in 1964.

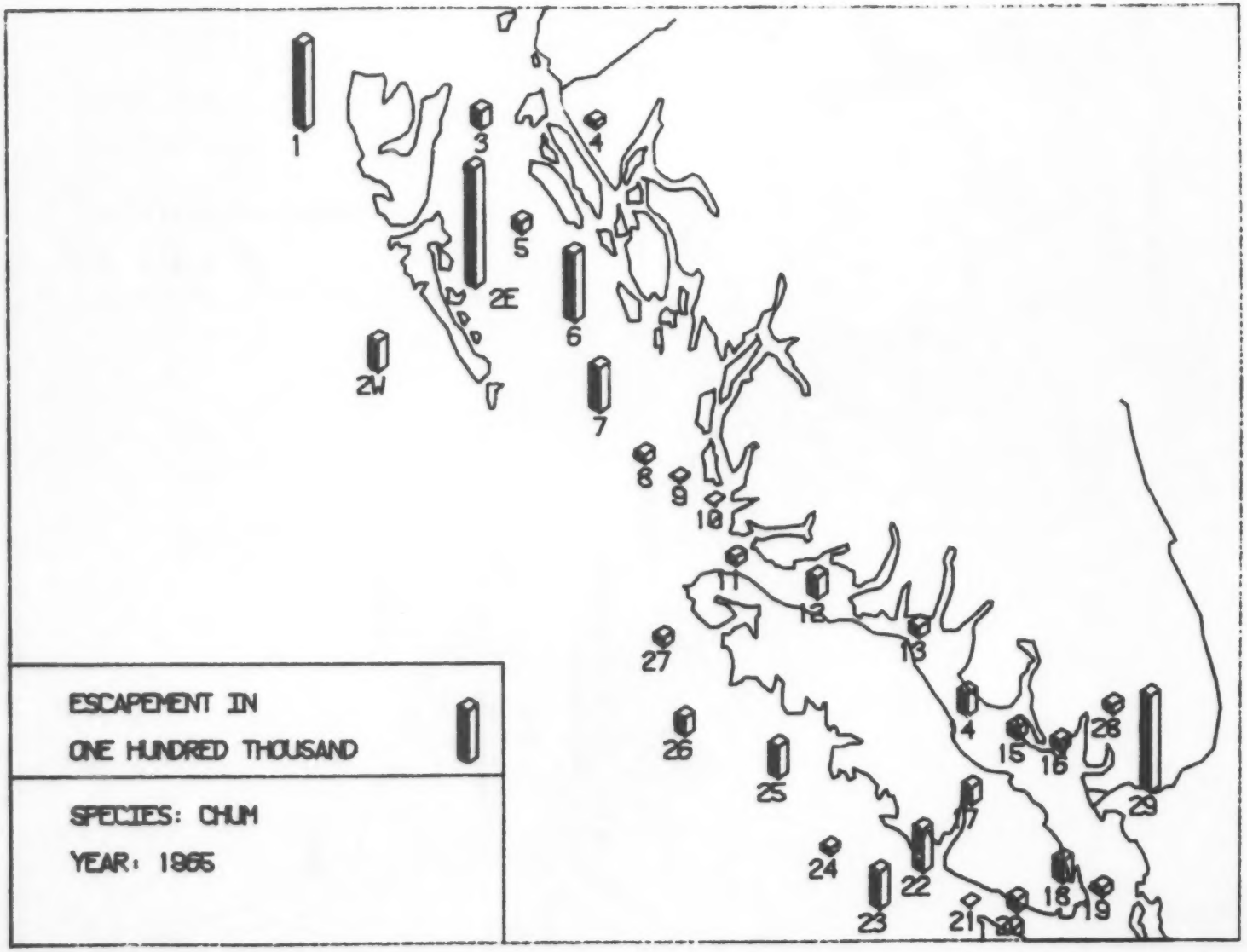

Fig. C15. Escapement of chum salmon by Statistical Area in 1965.

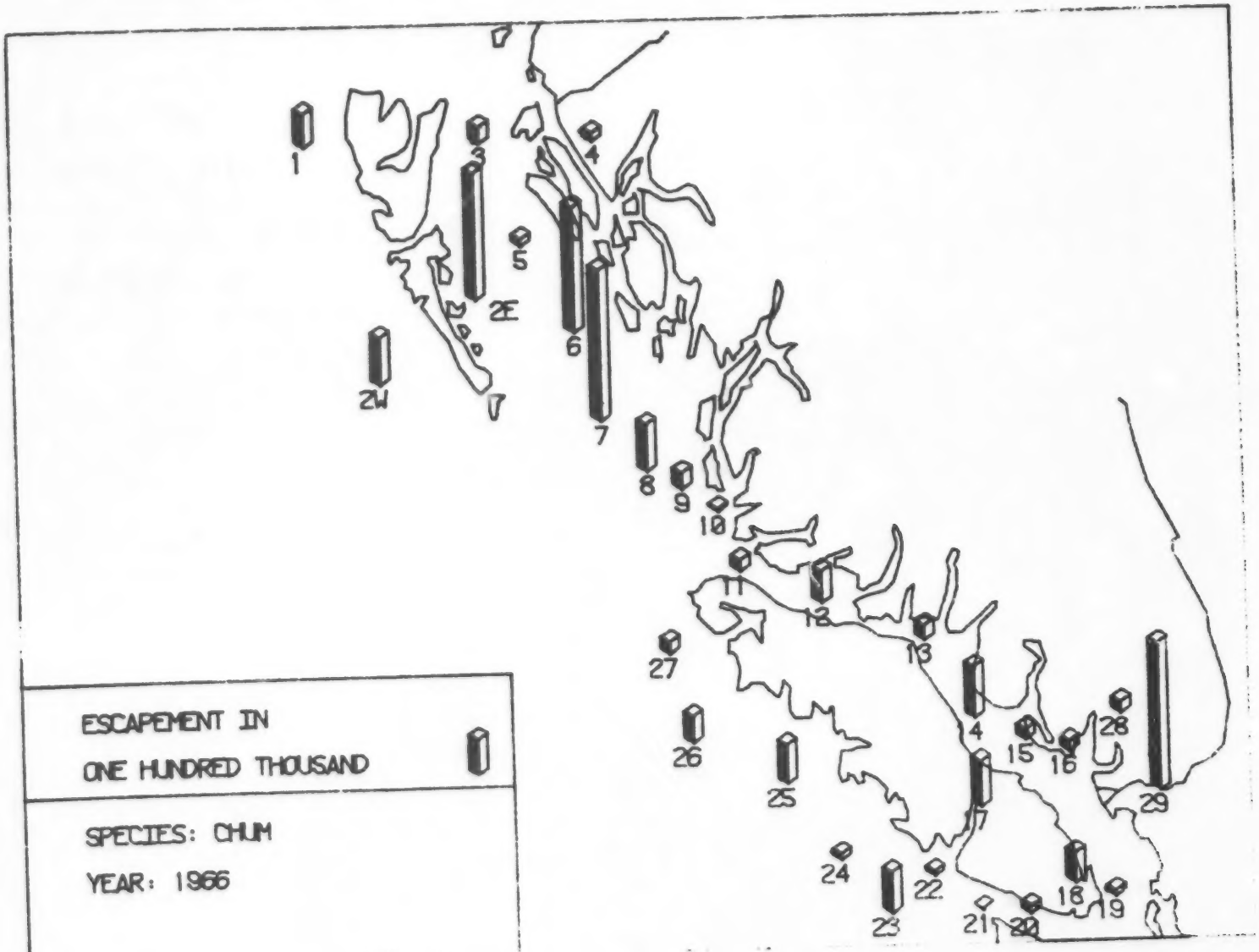

Fig. C16. Escapement of chum salmon by Statistical Area in 1966.

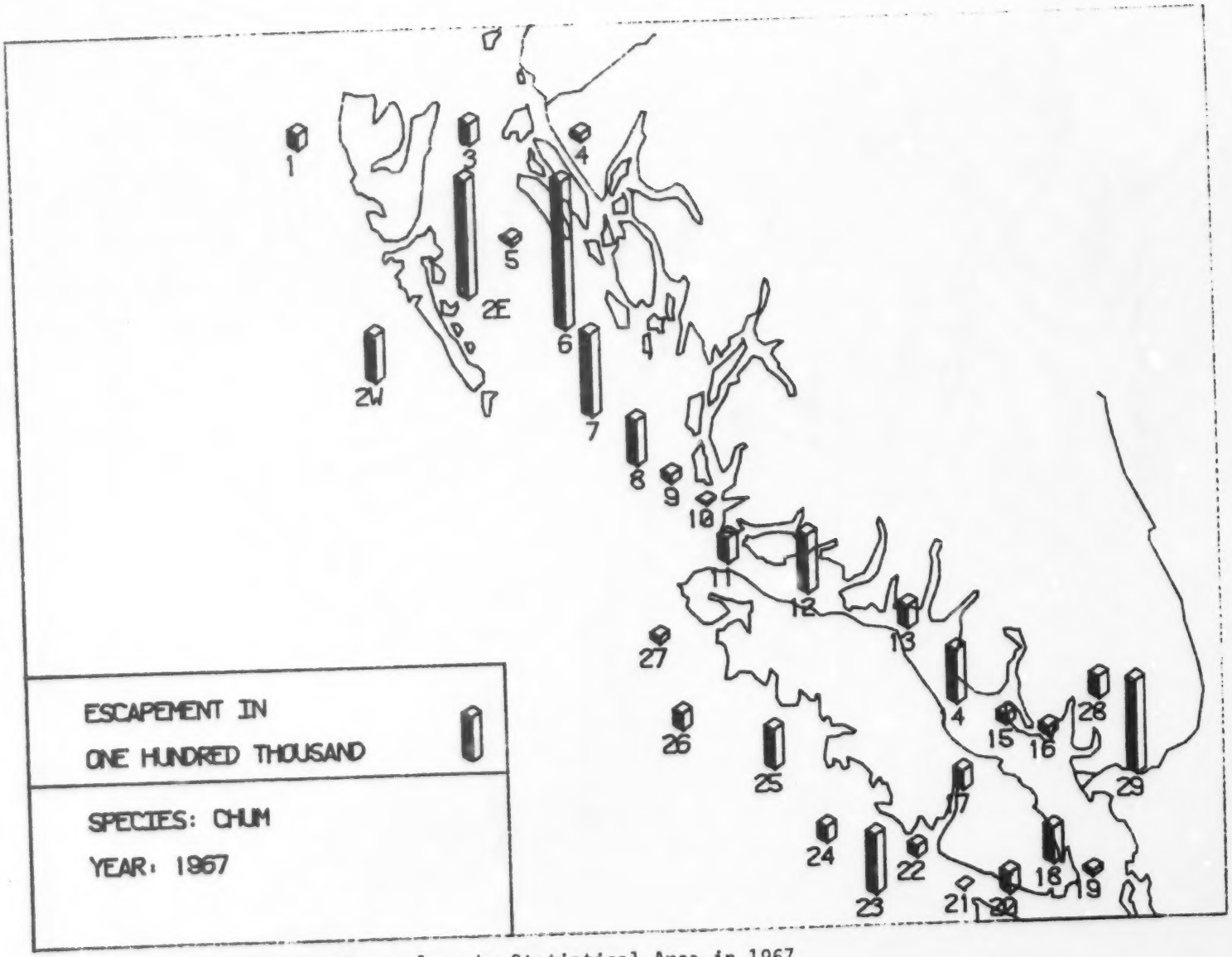

Fig. C17. Escapement of chum salmon by Statistical Area in 1967.

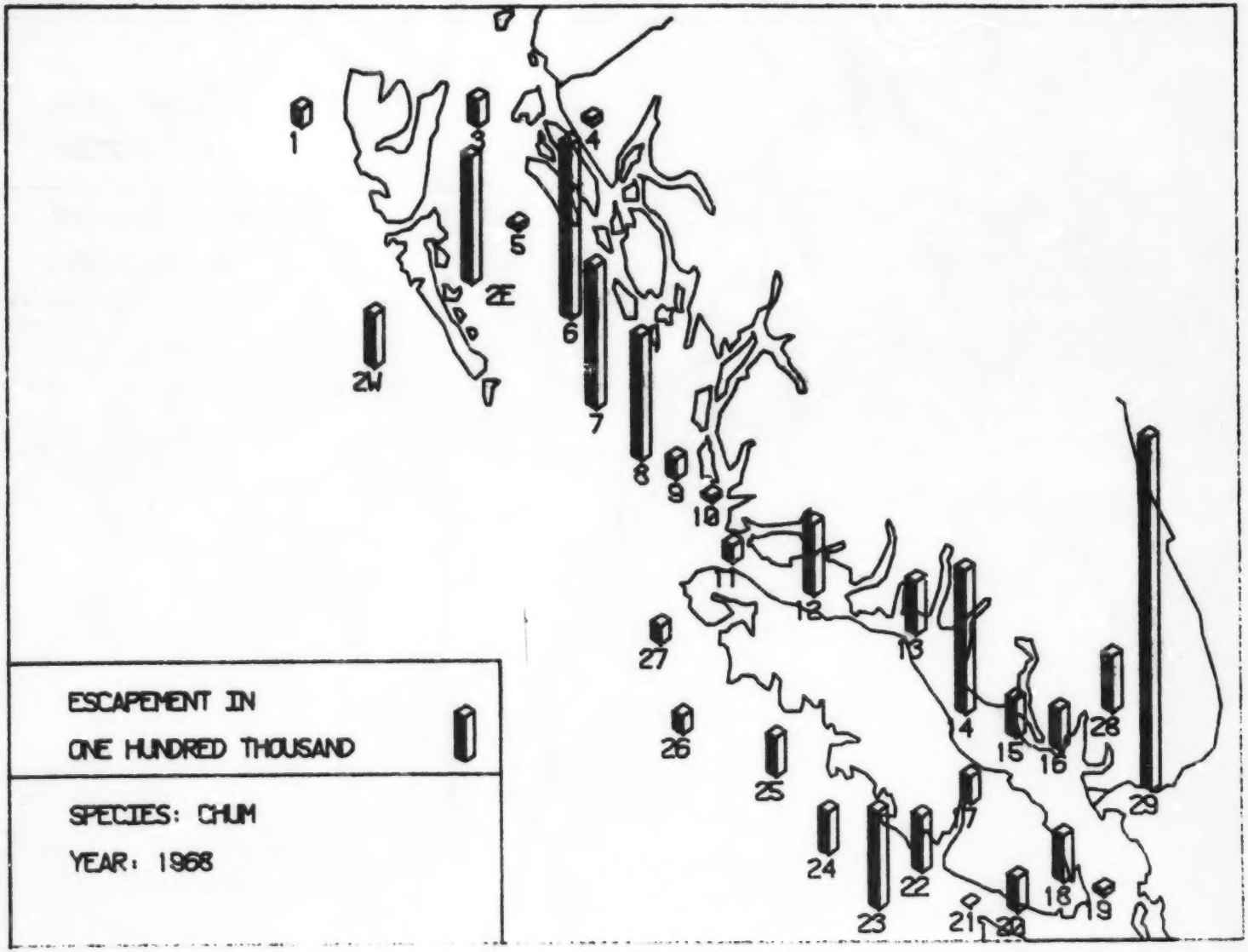

Fig. C18. Escapement of chum salmon by Statistical Area in 1968.

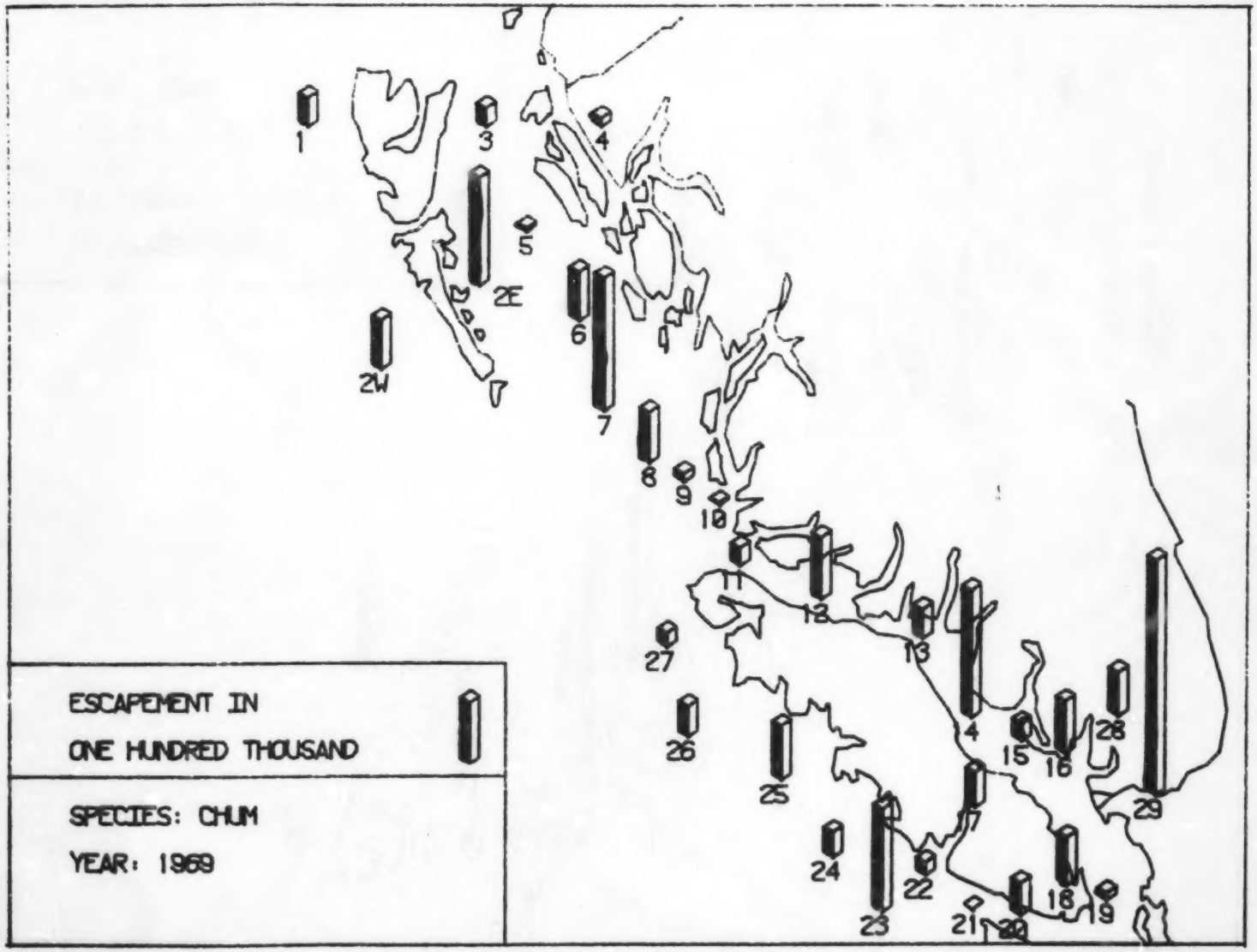

Fig. C19. Escapement of chum salmon by Statistical Area in 1969.

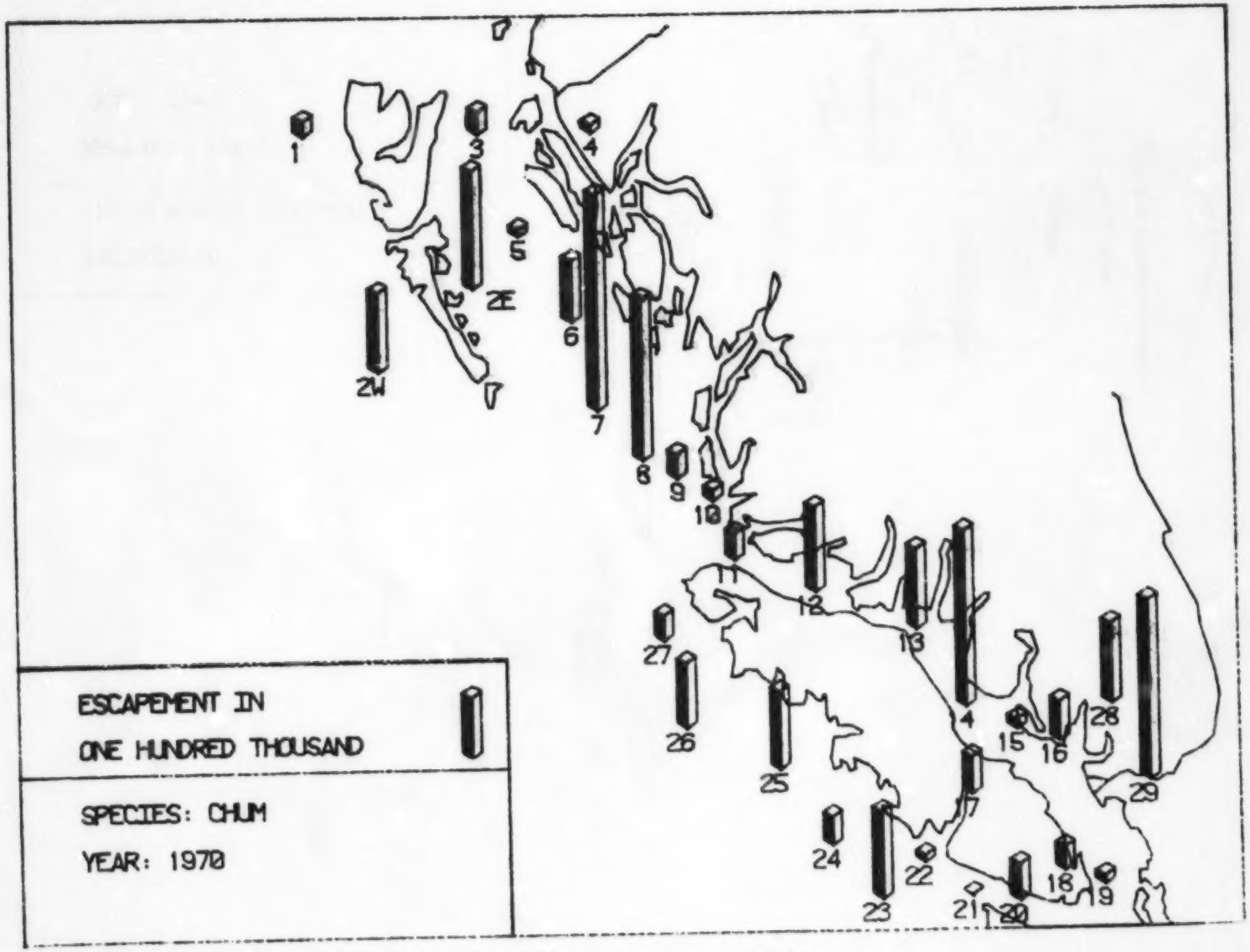

Fig. C20. Escapement of chum salmon by Statistical Area in 1970.

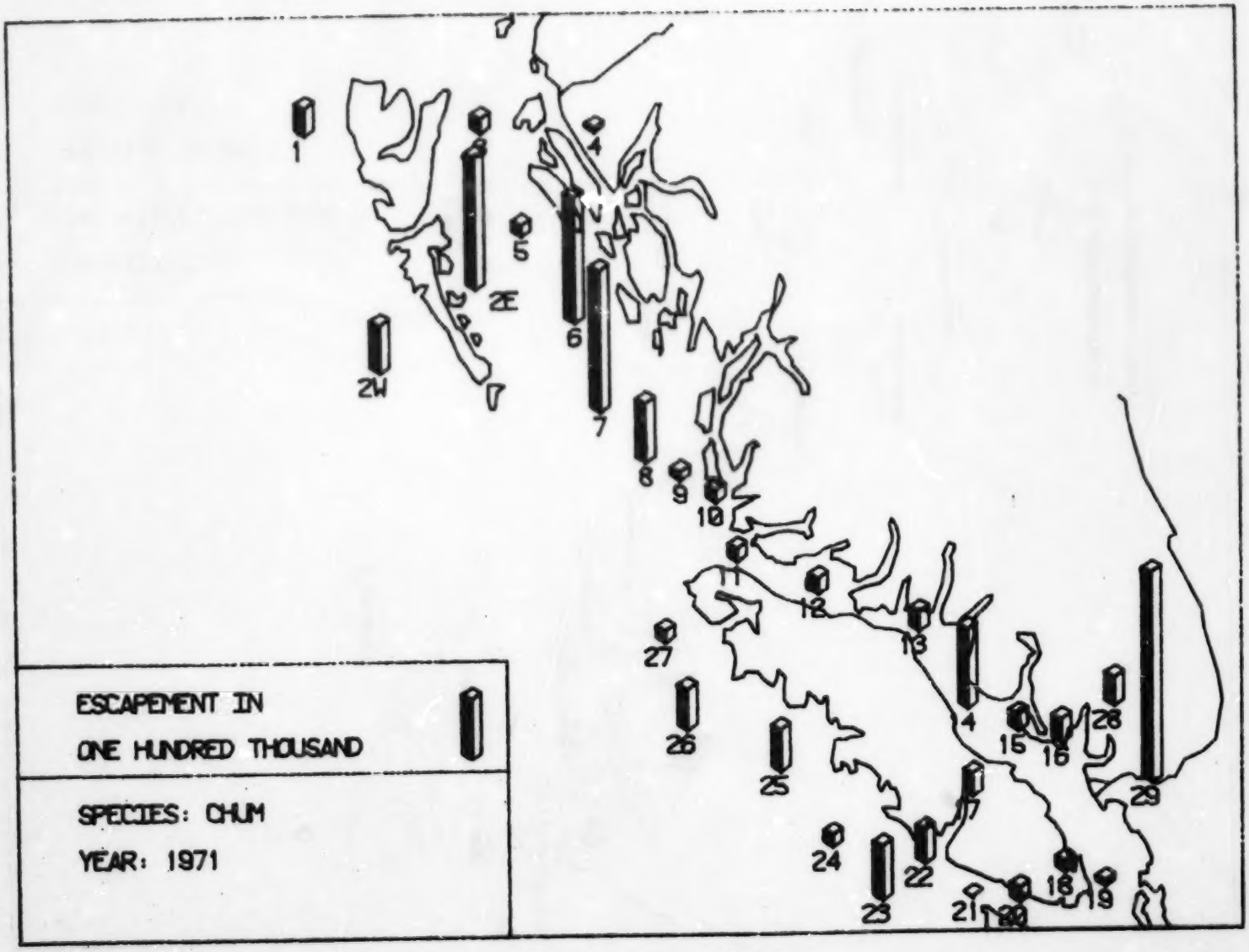

Fig. C21. Escapement of chum salmon by Statistical Area in 1971.

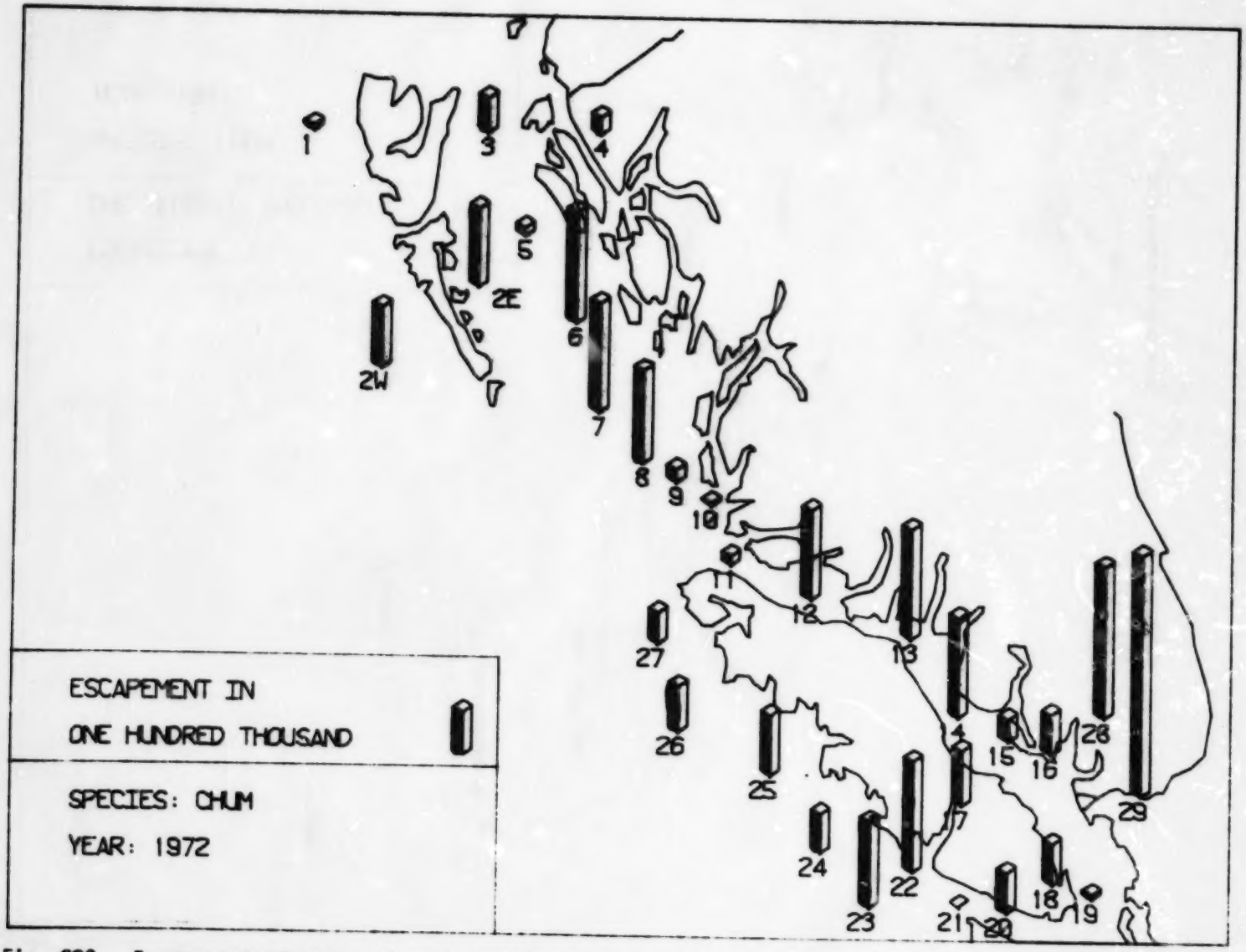

Fig. C22. Escapement of chum salmon by Statistical Area in 1972.

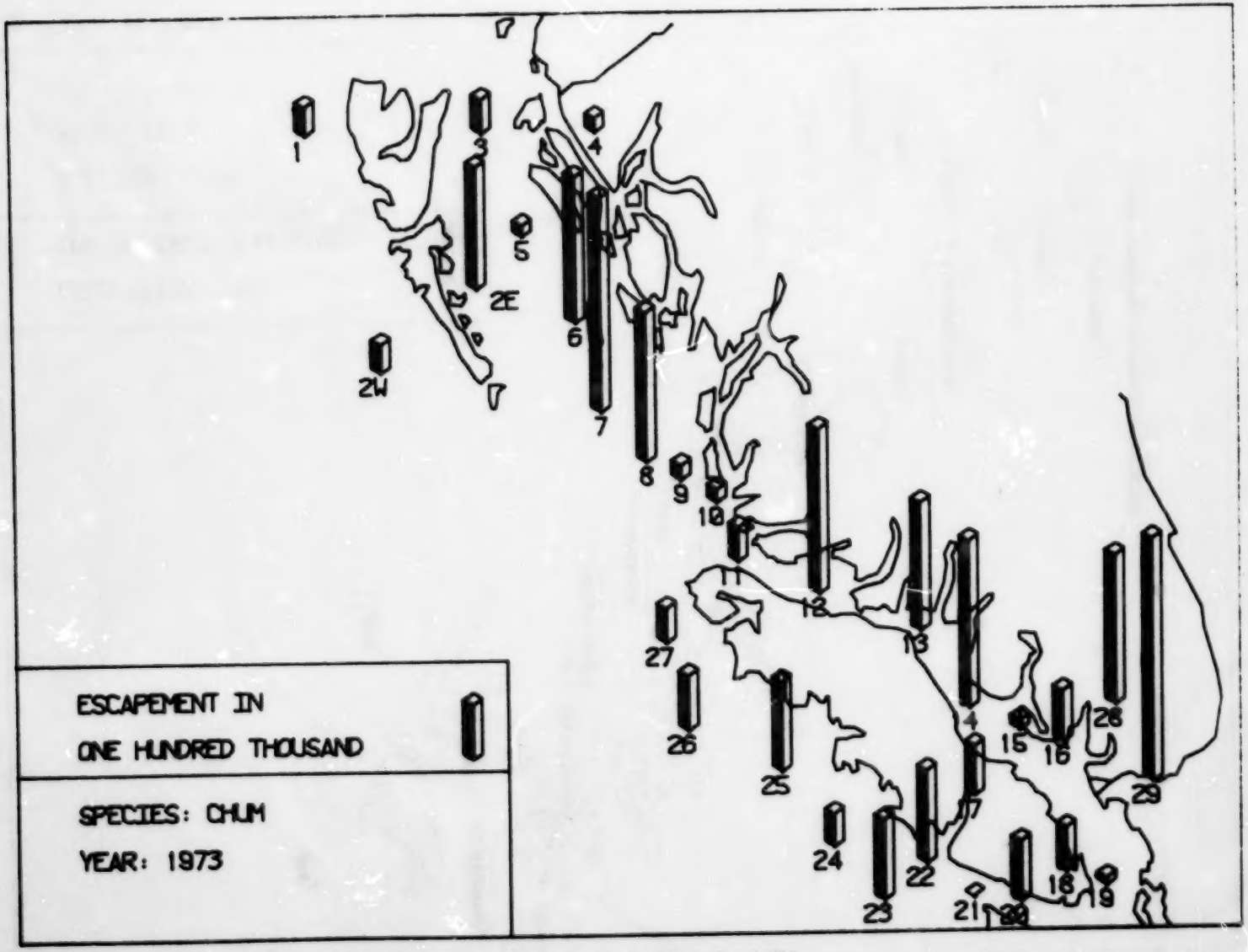

Fig. C23. Escapement of chum salmon by Statistical Area in 1973.

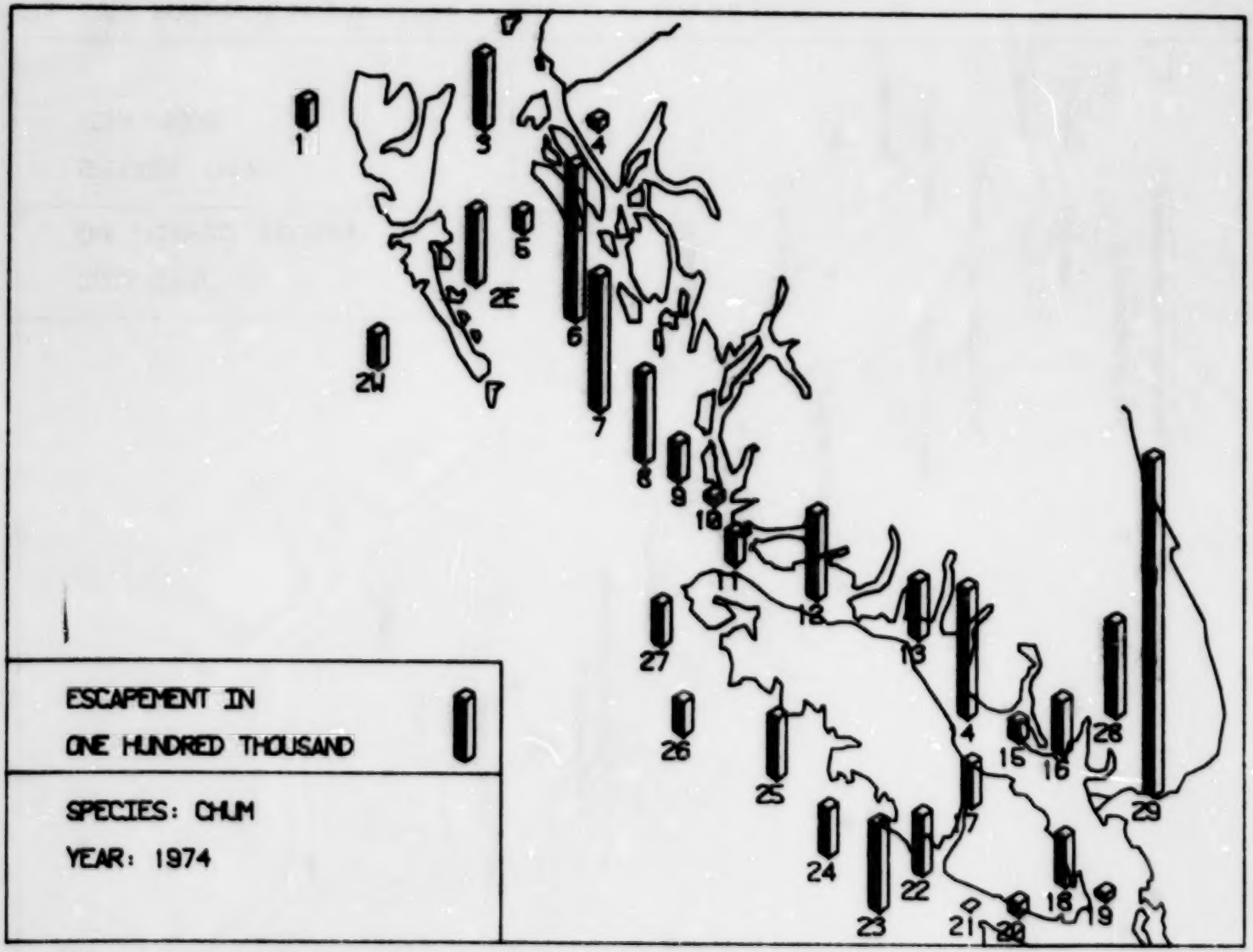

Fig. C24. Escapement of chum salmon by Statistical Area in 1974.

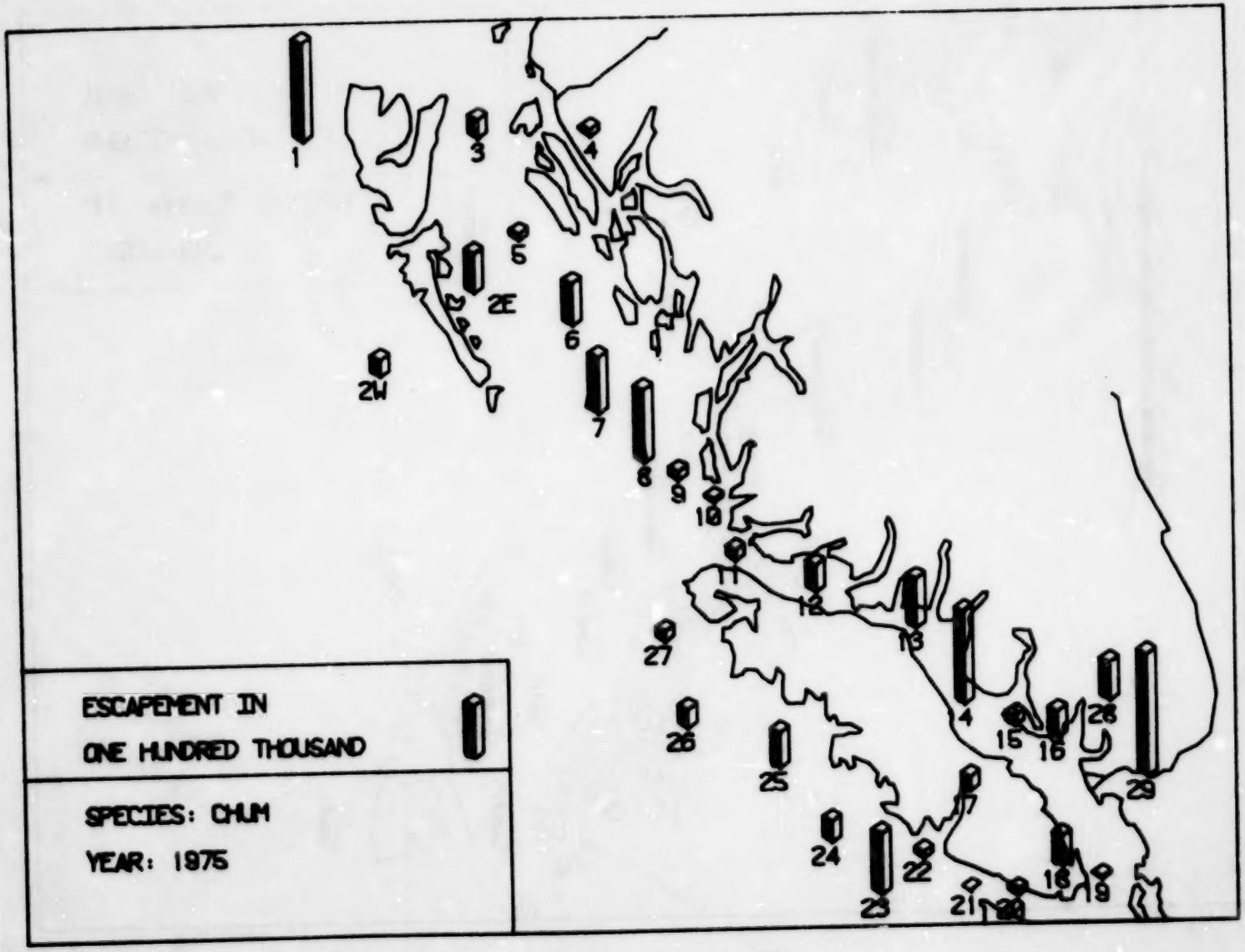

Fig. C25. Escapement of chum salmon by Statistical Area in 1975.

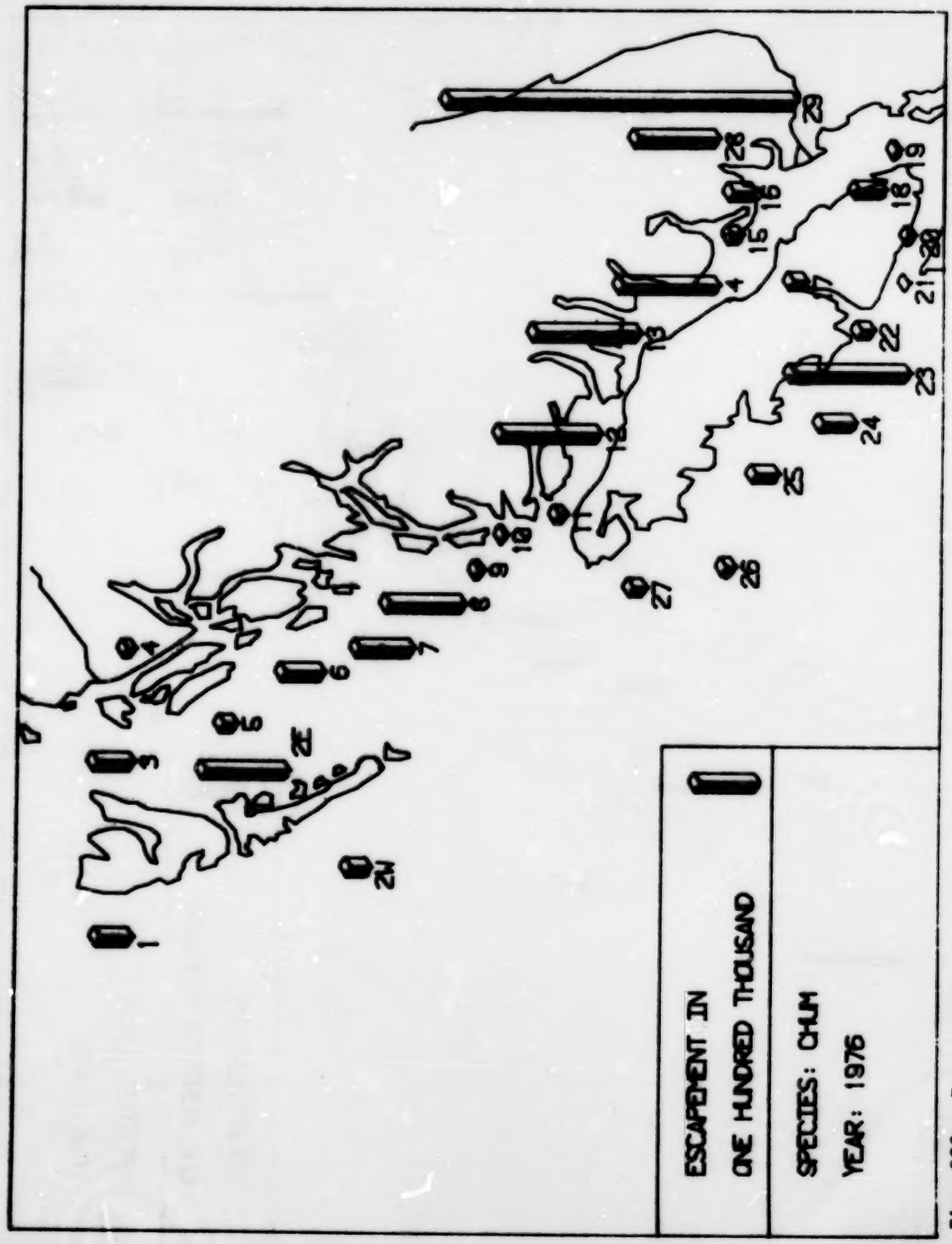

Fig. C26. Escapement of chum salmon by Statistical Area in 1976.

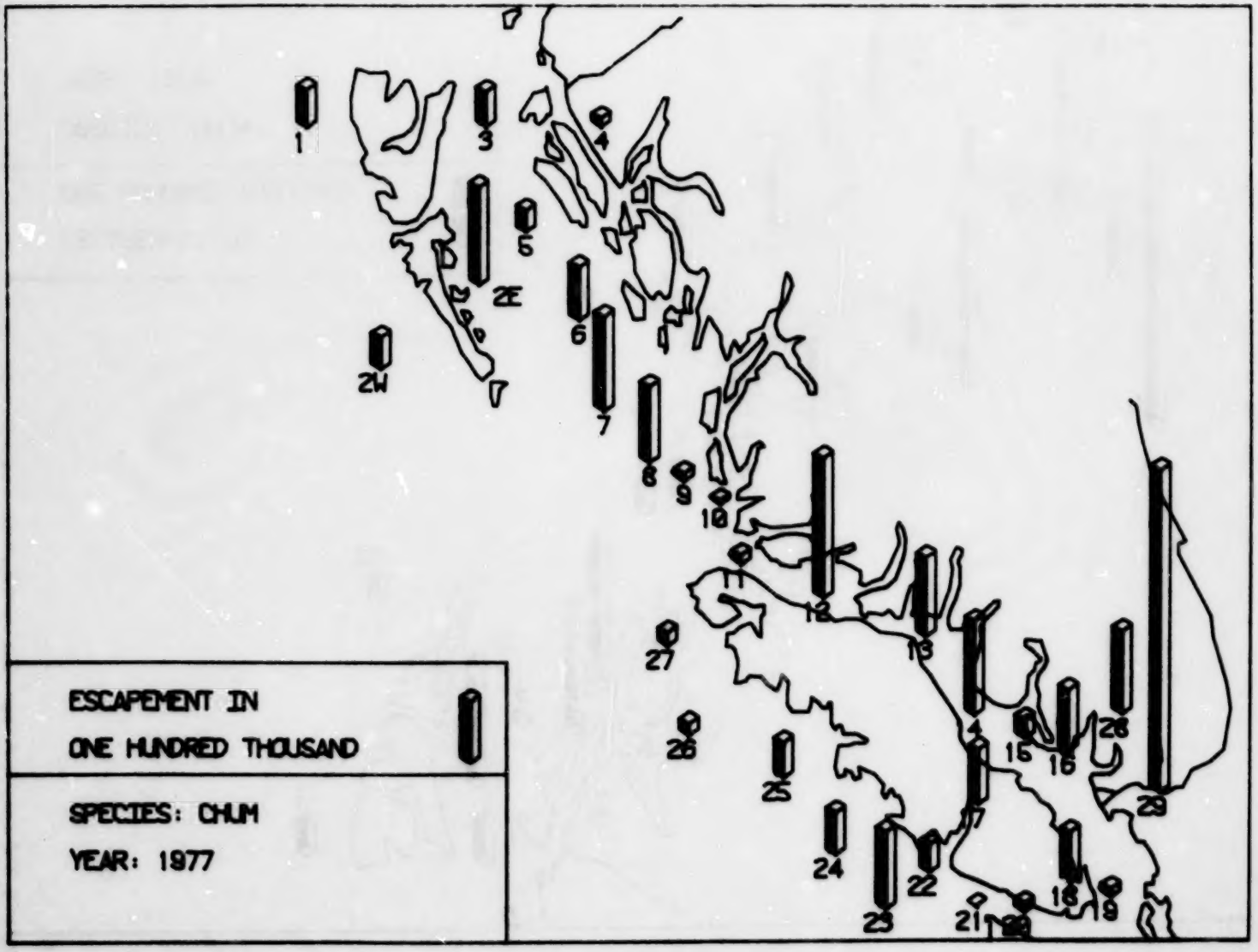

Fig. C27. Escapement of chum salmon by Statistical Area in 1977.

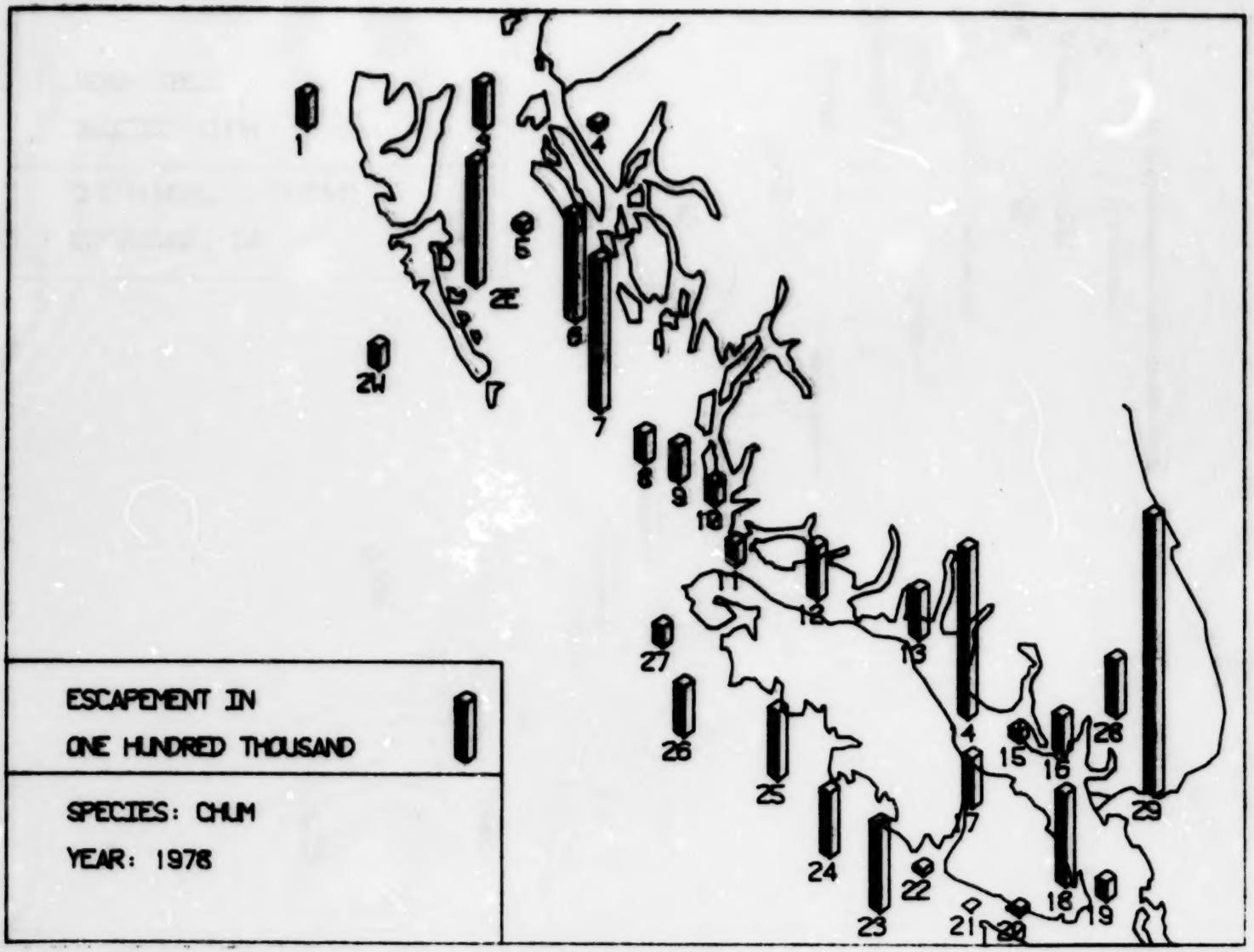

Fig. C28. Escapement of chum salmon by Statistical Area in 1978.

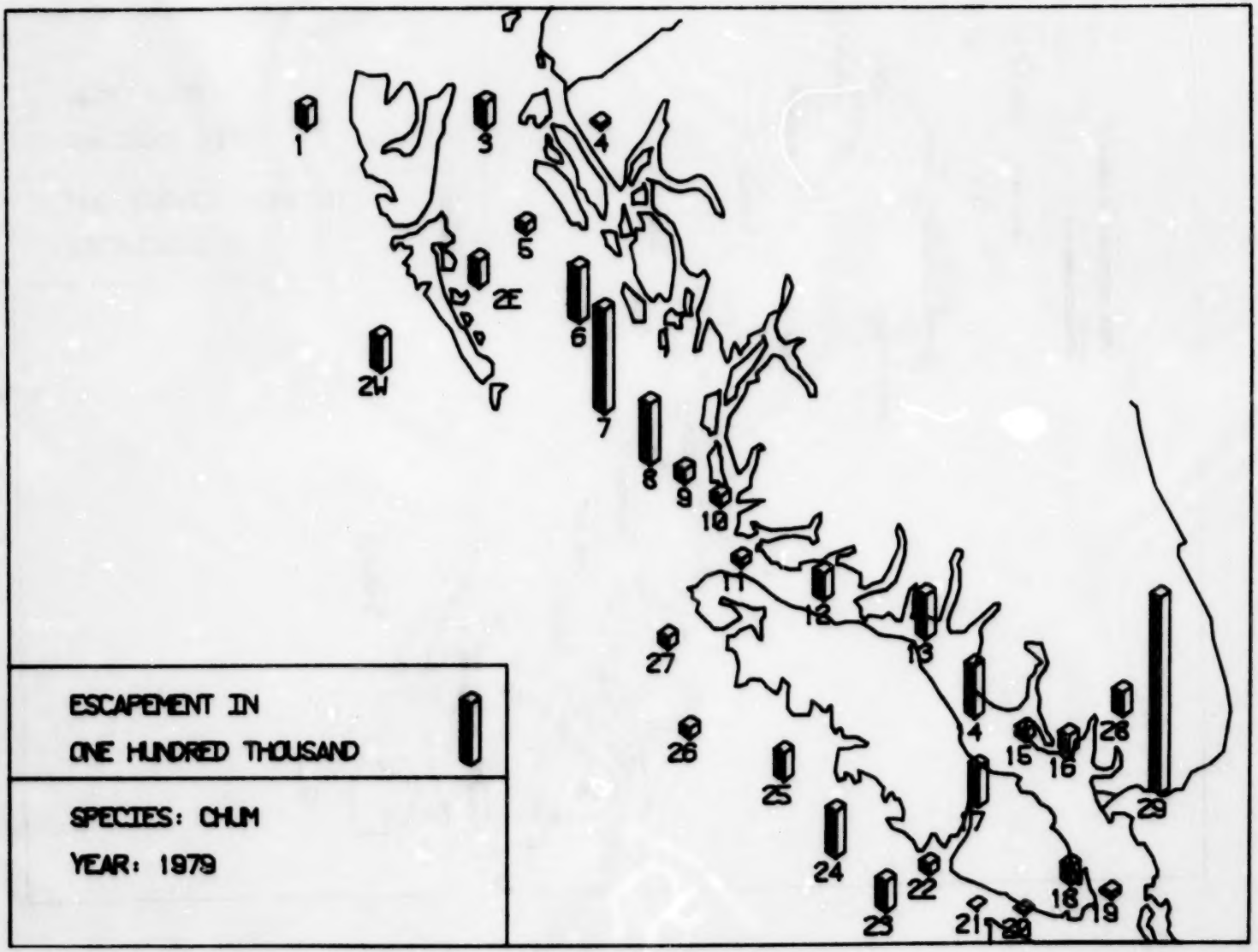

Fig. C29. Escapement of chum salmon by Statistical Area in 1979.

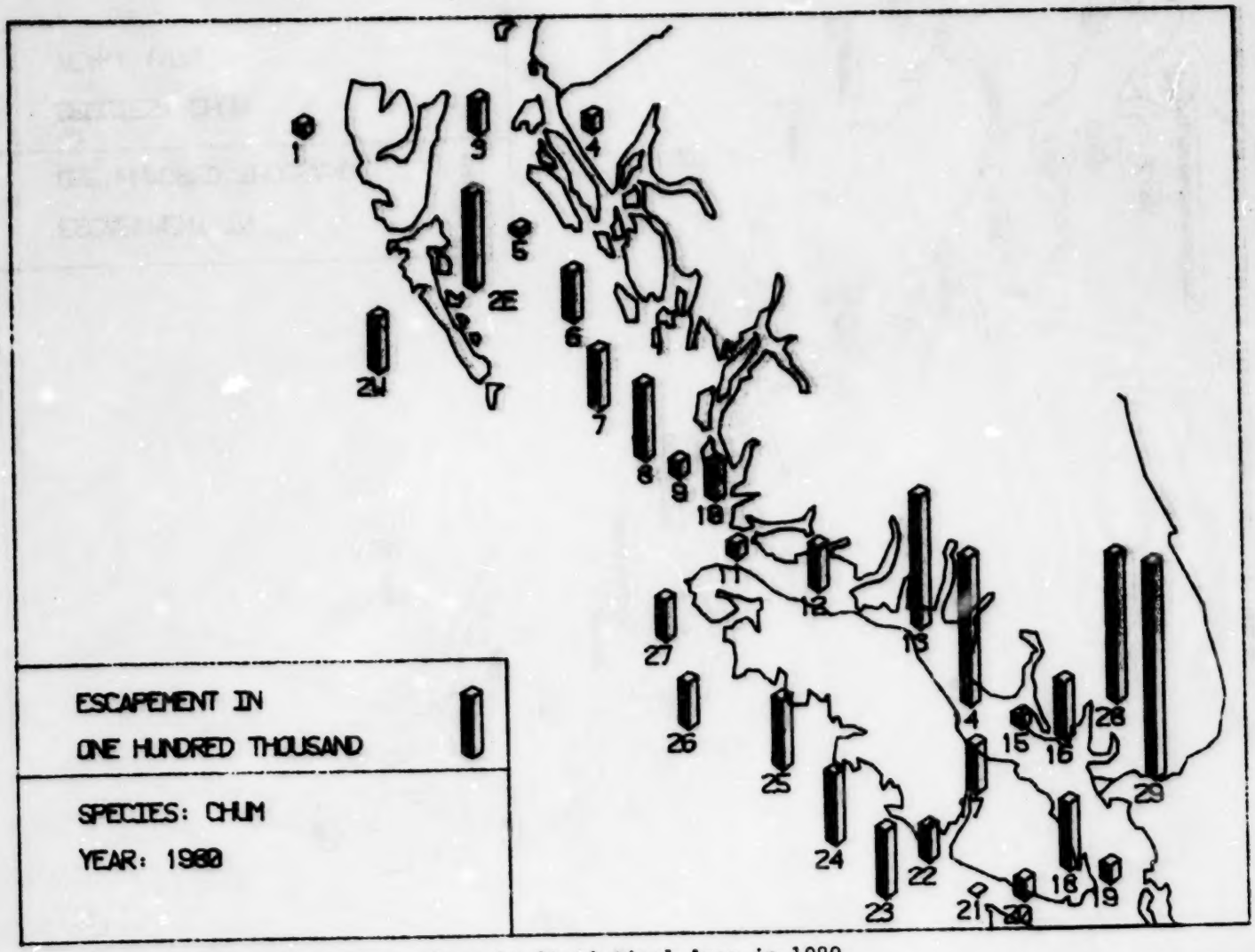

Fig. C30. Escapement of chum salmon by Statistical Area in 1980.

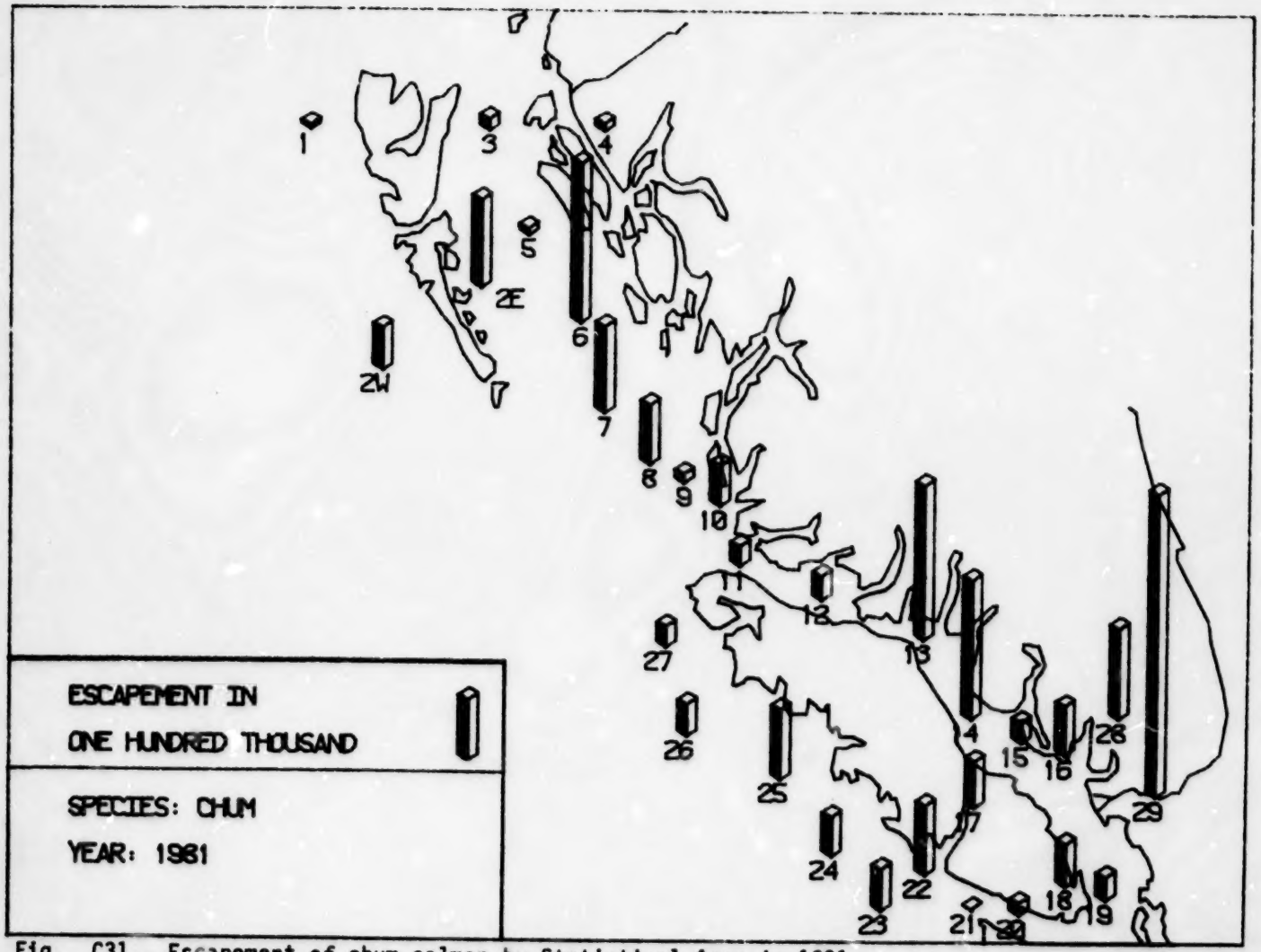

Fig. C31. Escapement of chum salmon by Statistical Area in 1981.

APPENDIX D

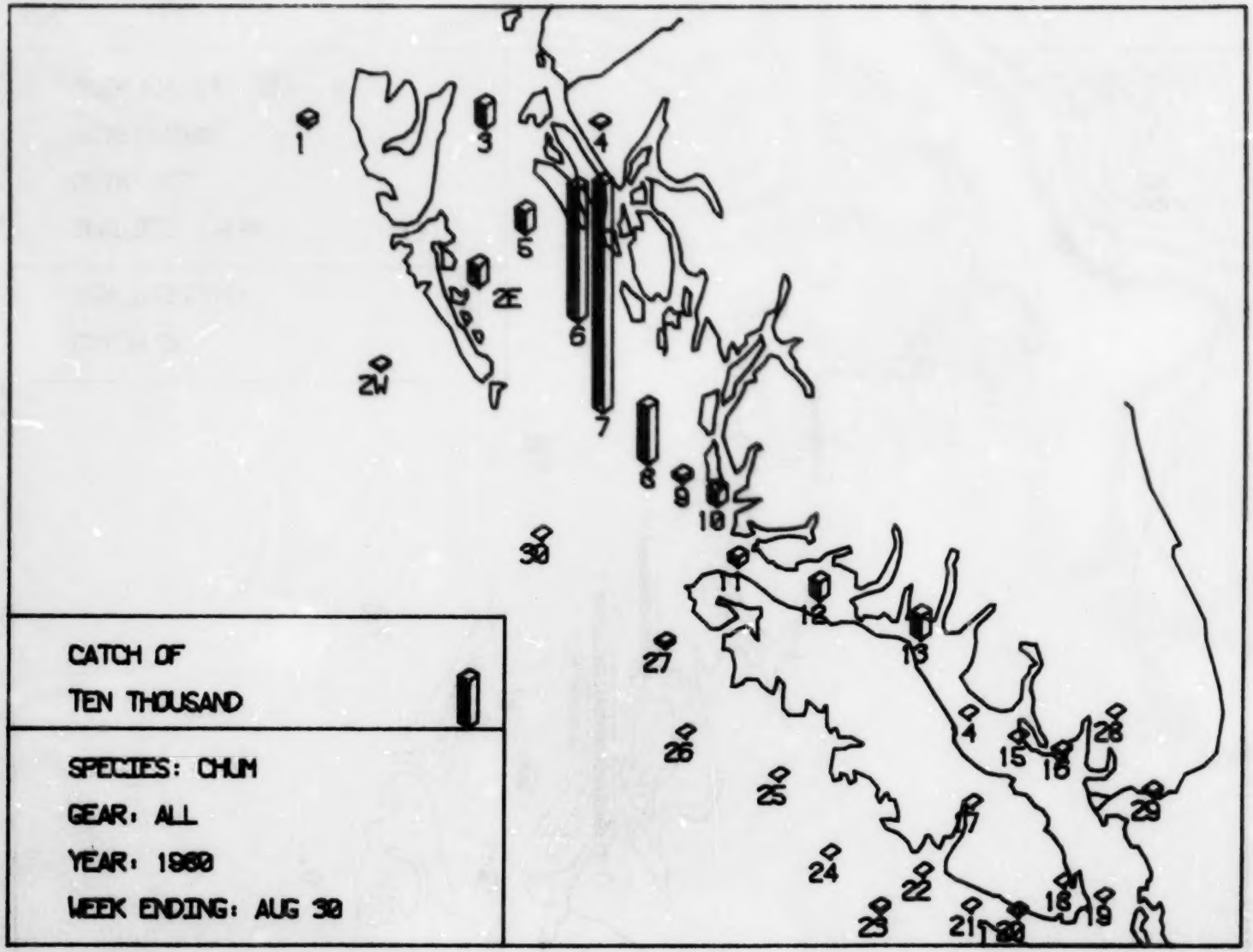

Fig. D1. Catch of chum salmon by Statistical Area for week ending August 30, 1980.

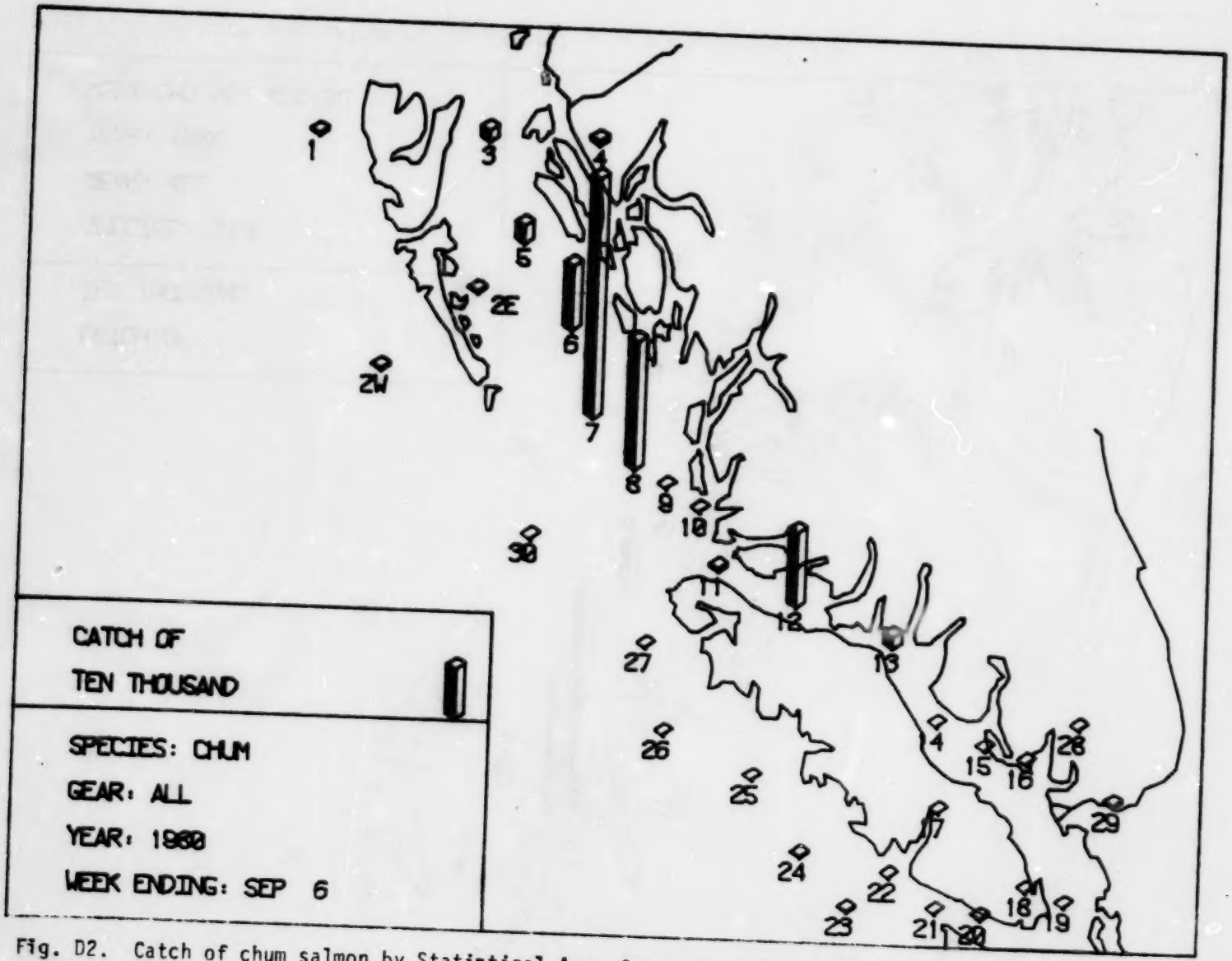

Fig. D2. Catch of chum salmon by Statistical Area for week ending September 6, 1980.

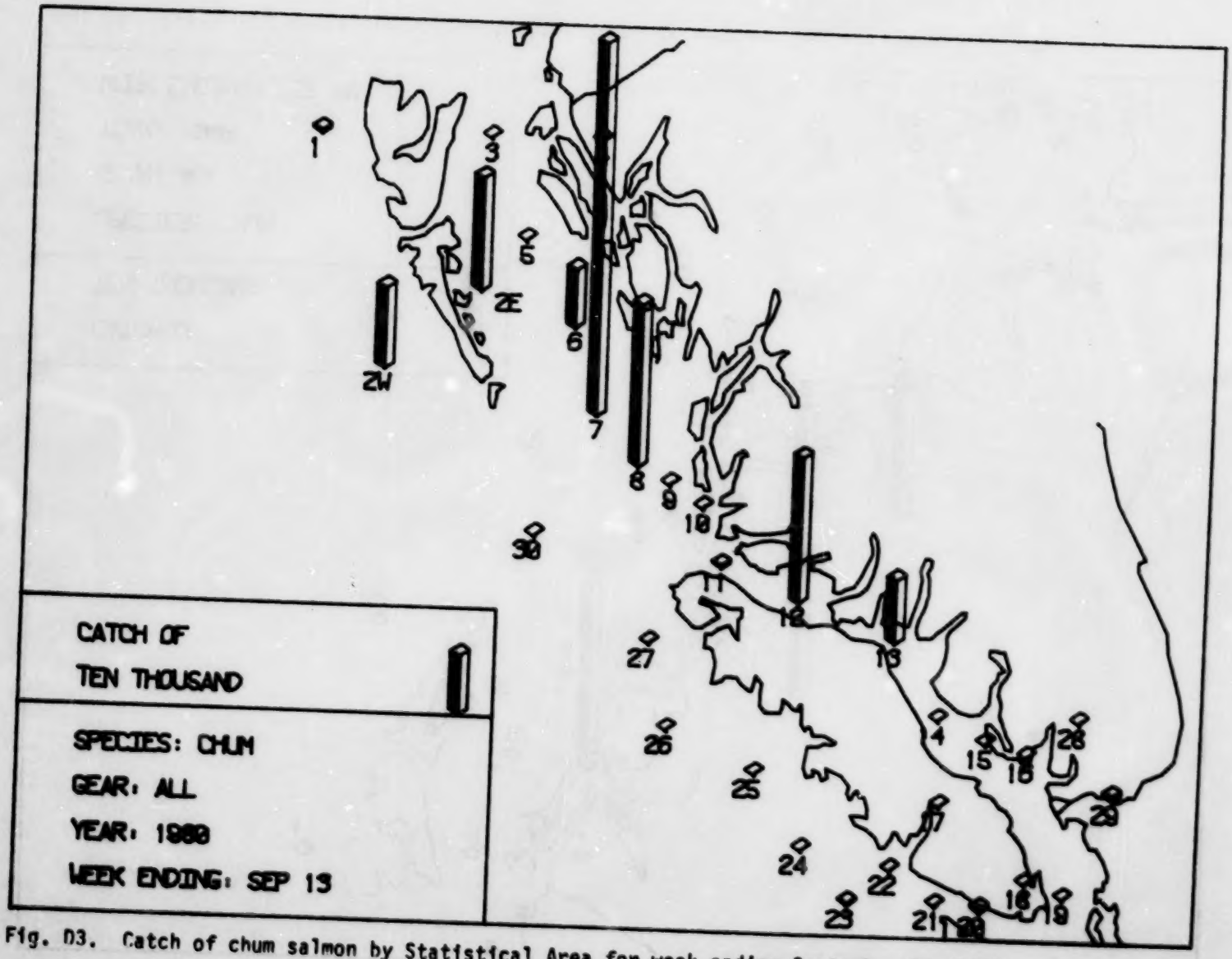

Fig. D3. Catch of chum salmon by Statistical Area for week ending September 13, 1980.

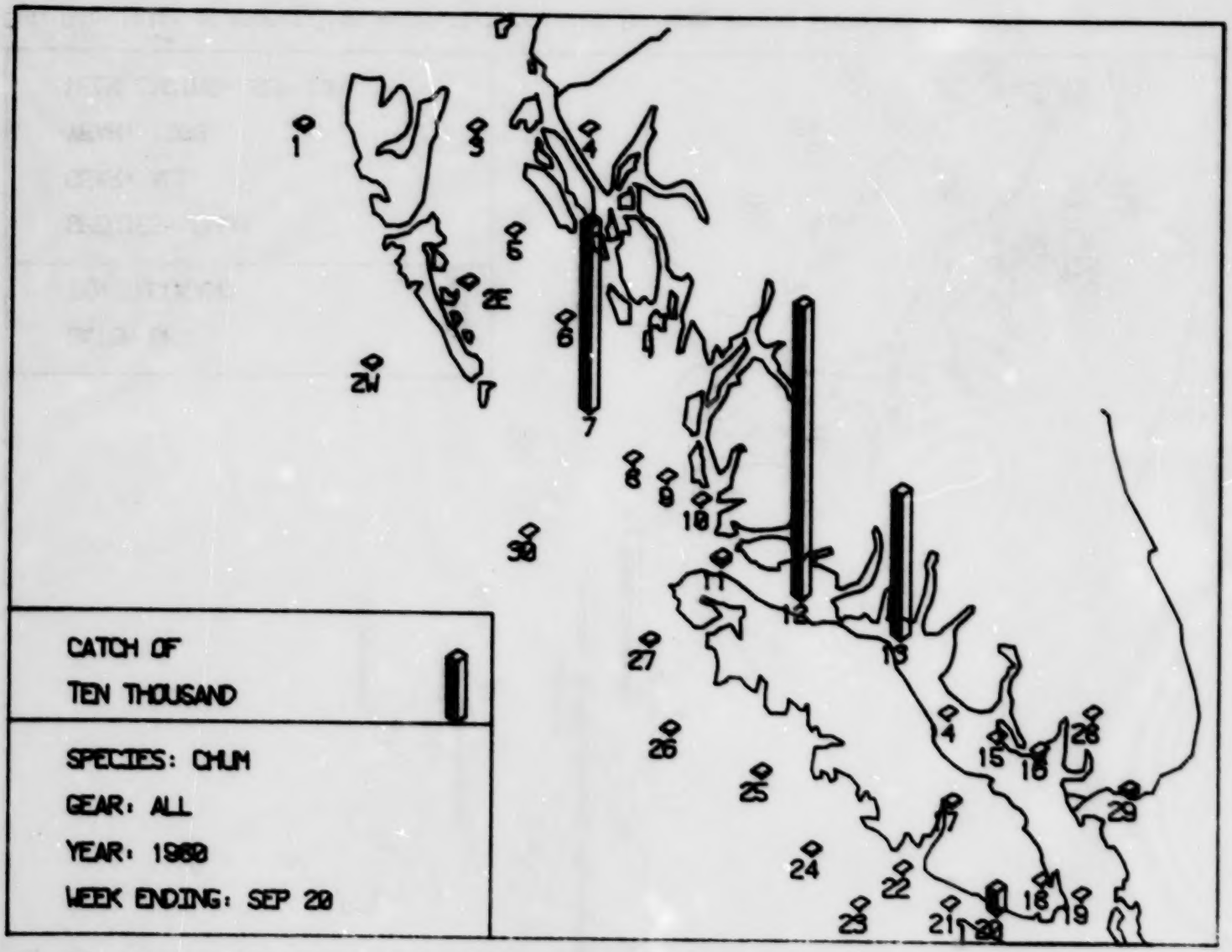

Fig. D4. Catch of chum salmon by Statistical Area for week ending September 20, 1980.

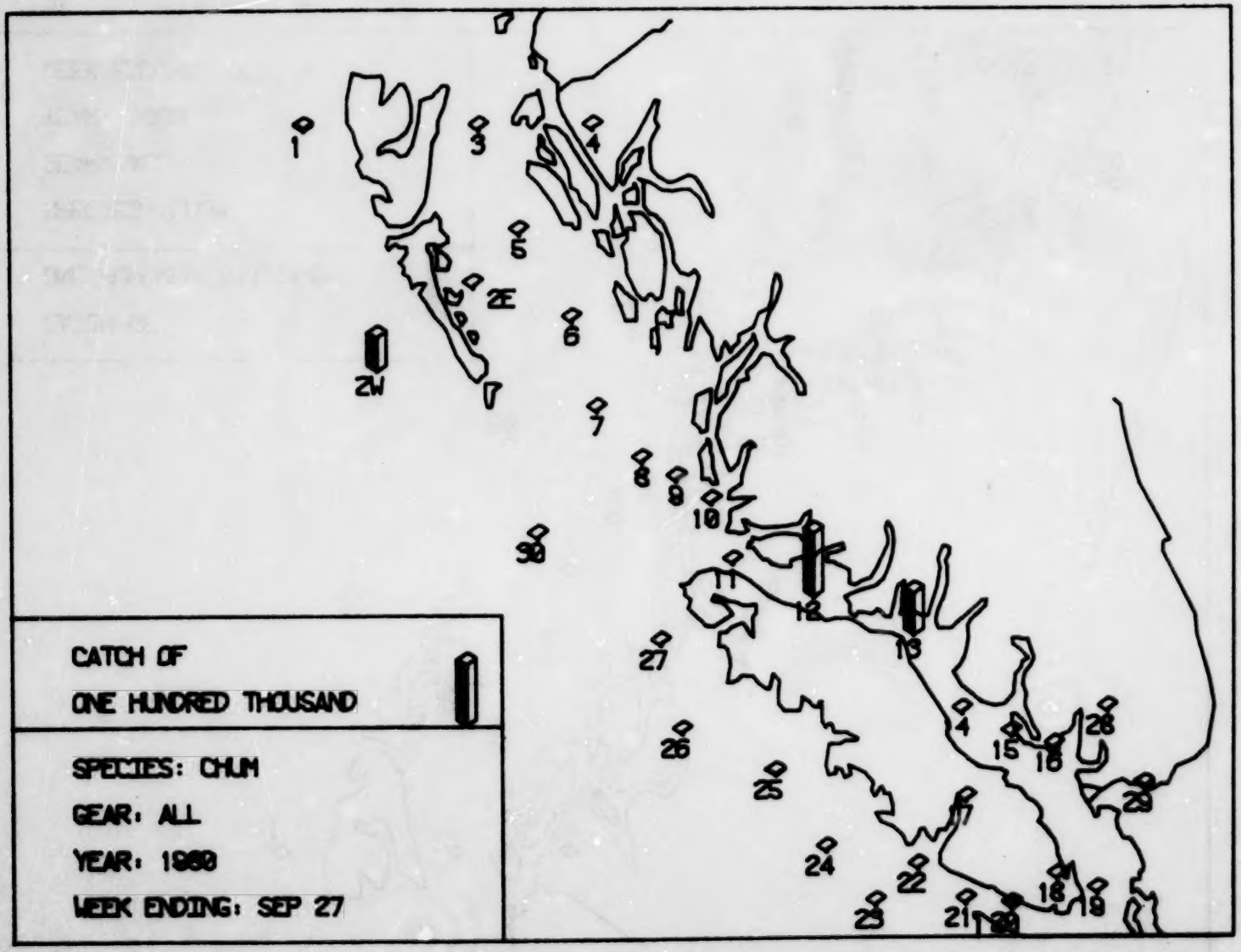

Fig. 05. Catch of chum salmon by Statistical Area for week ending September 27, 1980.

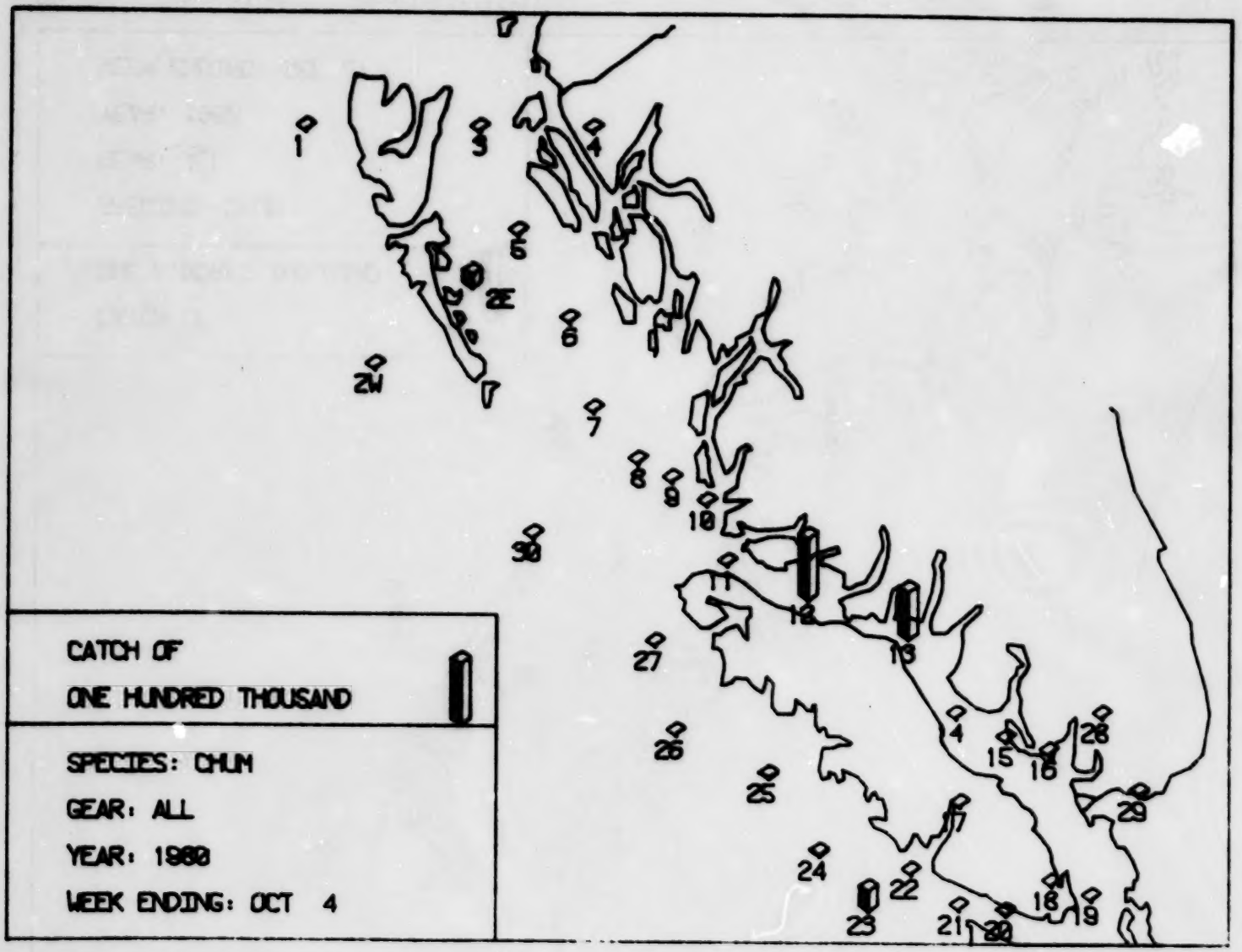

Fig. D6. Catch of chum salmon by Statistical Area for week ending October 4, 1980.

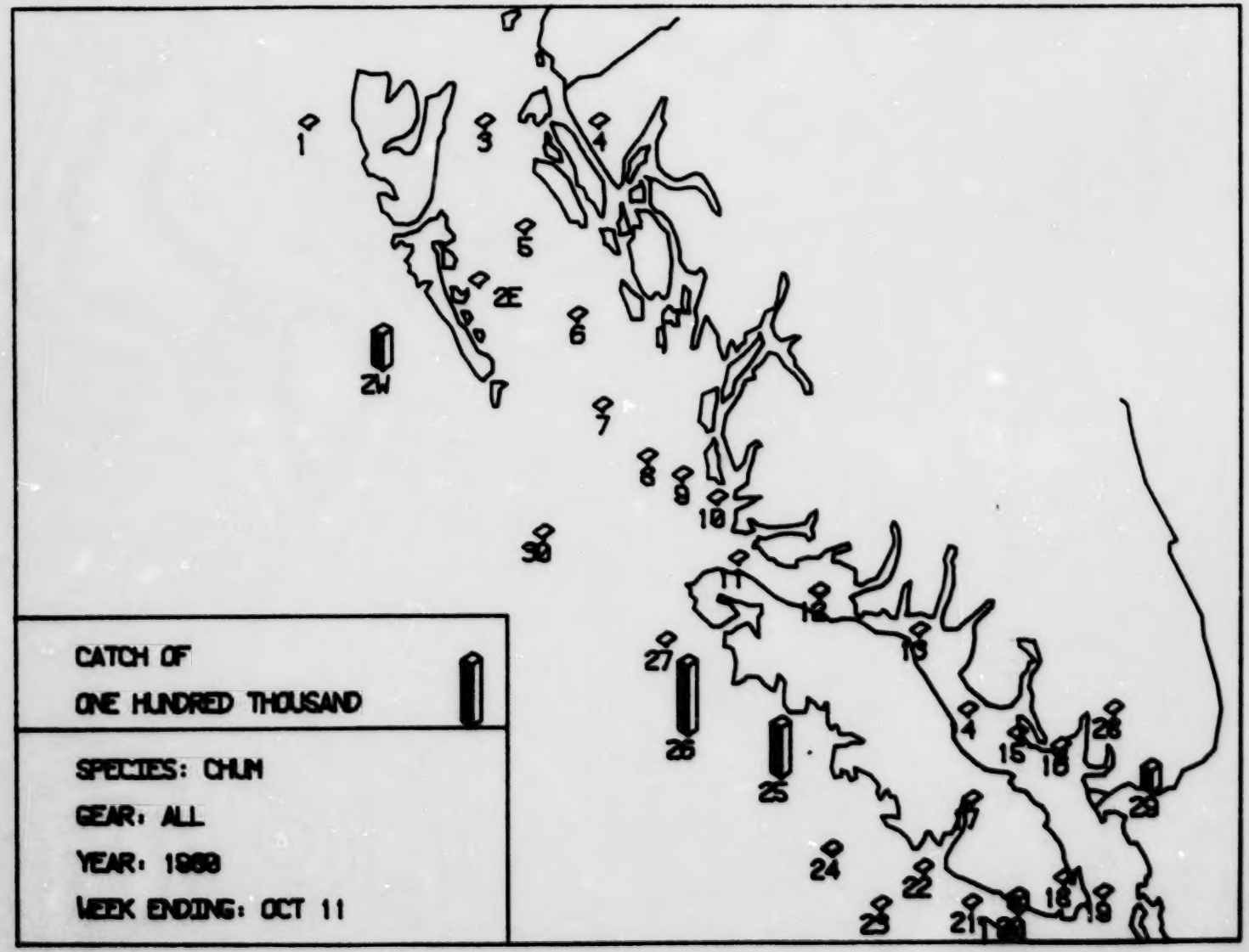

Fig. D7. Catch of chum salmon by Statistical Area for week ending October 11, 1980.

POOR

QUALITY

ORIGINAL